4 1CU
8-29-02

INITIAL SCREENING OF INCOMING PAPERS CHECKLIST

Reviewer: KMaze Date: 12-27-02

APPLICATION NO. 09/840080

1. PETITION TYPE CODE

_____R137(a) Petition-------- -501
_____R137(a) Petition --------509
(Issue Fee/Dwgs)
_____R137(b) Petition----------502
_____R137(b) Petition----------510
(Issue Fee/Dwgs)
_____R137(f) Petition----------536
_____R182 Petition----------519
_____R183 Petition----------503
_____R378(b) Petition----------532
_____R378(c) Petition----------533
_____R377 Petition----------521
_____R3.81(b) Petition---------523
_____R181 Petition----------515
_____R181 Petition----------504

PETITION TYPE CODE

_____R28c Peition----------309
_____R47 Petition----------313
_____R53(e) Petition----------408
_____R53 (R62 filing date)-----410
_____R10 Petition----------411
_____Lost Application----------412
_____R78(a)(3) Petition----------535
_____R78(a)(6) Petition----------535
_____R55(c) Petition----------535
_____R314 Petition----------508
_____R55(a) Petition----------507
_____Pet. W/D Abn----------525
_____R705(b) PTA-Bef iss------550
_____R705(d) PTA-Aft iss-------551
_____R705(c)PTA-SpiteDueCare-552
_____Other_____

2. LIST PAPERS FILED WITH PETITIONS

_____PreAmdt/Amdt	_____CPA	_____Associate POA
_____Filing Fees	_____RCE	_____Terminal Disclaimer
_____Reply/Arguments	_____IDS	_____Change of Address
_____Election	_____129(a) Submsn	_____Revocation/Poa
_____Notice of Appeal	_____Issue Fee	_____Priority Documents
_____Brief (3)	_____Drawings	_____Oath/Decl. & POA
_____Reply Brief	_____Rule 312 Amdt	_____Rescind Non-Pub Req.
_____Declaration R132	_____Ext Time (___)	_____Statement 3.73(b)

Other Papers_____

3. Is paper a petition to withdraw holding of abandonment: _____yes_____no
If so, send paper and/or file to appropriate location ***(Note: remove any flag set first)***:

a. Nonreceipt of action from TC or assertion that reply was timely filed:
Send paper to TC_____
b. Nonreceipt of Missing Parts Notice or assertion that reply was timely filed:
Send paper to DIRECTOR -OIPE - -CP2-7D25 (PH: 308-0910)
c: Assertion of timely payment of issue fee and/or submission of drawings:
Send petition to Office of Publications: ATTN: Tom Hawkins
d. Other_____

4. Other:_____
If not handled in Office of Petitions, send paper to appropriate location.

5. Is petition accompanied by assignment papers, fee address, or other paper which needs to be sent to another location? _____ yes _____ no If so, make copy of assignment papers, fee address, or other paper; mail original to proper location and place copy in file with an indication that the original paper(s) has been forwarded to the appropriate location (Assignment Branch; Maintenance Fee Division, etc.)

2161

2764

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:	)	Attorney Docket No. 23439-030-402
James JOHNSON, *et al.*	)	Group Art Unit: 2764
Serial No.: 09/840,080	)	Examiner: *Not yet assigned*
Filed: August 24, 2000	)	

For: REMOTE VEHICLE EMISSIONS SENSING DEVICE WITH SINGLE DETECTOR

PETITION FOR TWO-MONTH EXTENSION OF TIME UNDER 37 C.F.R. §1.136(a)
and
SECOND RENEWED PETITION UNDER 37 C.F.R. §1.47(b)

ATTN: BOX DAC
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

PETITION FOR TWO-MONTH EXTENSION OF TIME UNDER 37 C.F.R. §1.136(a)

The Petitioner respectfully requests a two-month extension of time under 37 C.F.R. § 1.136(a) for responding to a Decision on Petition Under 37 C.F.R. §1.47(b) ("Decision"), mailed **August 29, 2002** in the above-captioned patent application. Accordingly, it is respectfully requested that a two-month extension of time until **December 29, 2002**, be granted.

A check in the amount of $400.00 is attached to cover the two-month extension fee. In the event that any variance exists between the amount enclosed and the appropriate fees, please charge or credit any difference to the undersigned's Deposit Account No. 50-0311.

12/19/2002 MBERHE 00000073 09840080
01 FC:1252 400.00 OP

#9

SECOND RENEWED PETITION UNDER 37 C.F.R. §1.47(b)

In response to the Decision on Petition Under 37 C.F.R. §1.47(b) ("Decision"), mailed August 29, 2002, Petitioner respectfully submits this Second Renewed Petition Under 37 C.F.R. §1.47(b). In response to the Decision, Petitioner respectfully submits the following remarks:

A grantable petition under 37 C.F.R. §1.47(b) requires:

(1) The petition fee;
(2) A surcharge if the petition was not filed at the time of filing of the application;
(3) A statement of the last known address of each of the non-signing inventors;
(4) Proof that a copy of the application was sent or given to each of the non-signing inventors for review;
(5) Proof that each of the non-signing inventors refused to sign;
(6) Proof that the Rule 47(b) Applicant has sufficient proprietary interest in the subject matter to justify the filing of the application;
(7) Proof of irreparable damage, and;
(8) An acceptable oath or declaration in compliance with 35 U.S.C. §§115 and 116 and 37 C.F.R. §1.63.

In the Decision, it is alleged that Petitioner has satisfied all requirements, with the exception of requirements (4) and (5). *See* Decision, pg.2. Although Petitioner respectfully disagrees with the findings regarding requirements (4) and (5), further clarification is provided below for each of the inventors: James H. Johnson and John DiDomenico.

1. **James H. Johnson**

a. **Requirement (4): Proof that a copy of the application was sent or given to each of the non-signing inventors for review.**

Petitioner respectfully submits **Exhibits A and B** as evidence that a copy of the above-captioned application was sent to James H. Johnson for his review.

Exhibit A includes a copy of a package sent on November 12, 2002, via FedEx Priority Overnight delivery, to the last known address of James H. Johnson, at 4401 West Crestfield Road, Tucson, Arizona 85475. The package included the following documents:

- Letter to James H. Johnson;
- Joint Declaration for Patent Application and Power of Attorney;
- Assignment;
- Copy of U.S. Patent Application Serial No. 09/840,080 titled: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR;" and
- Federal Express Return Envelope.

Also provided in **Exhibit A** are shipment tracking results, and a return shipment notice from FedEx indicating that a delivery attempt made on November 13, 2002 was unsuccessful due to an incorrect address. The package was returned to the undersigned.

Exhibit B provides evidence of a second attempt to contact James H. Johnson to provide him with copies of the above-referenced documents.

On November 19, 2002, the undersigned (Mr. Blaise) contacted MD Lasertech Limited in Tucson, Arizona, which was believed to be the current employer of James H.

Johnson. After confirming that James H. Johnson is an employee at MD Lasertech Limited, a company representative informed the undersigned that James H. Johnson's e-mail address is: Jim@md-lasertech.com.

Further, on November 19, 2002, the undersigned sent an e-mail to James H. Johnson at the above e-mail address (*in addition to various other possible variations of the e-mail address*) requesting that Mr. Johnson provide his current home address so that the package could be re-sent. This e-mail message is included in **Exhibit B**, along with a return receipt acknowledging that the e-mail message was successfully delivered to James H. Johnson.

b. **Requirement (5): Proof that each of the non-signing inventors refused to sign.**

The November 19, 2002 e-mail message to James H. Johnson (shown in **Exhibit B**), specifically requested that Mr. Johnson reply and provide his current home address within five days of the date of the e-mail message. The e-mail message further stated that no reply on the part of Mr. Johnson would be considered a refusal to cooperate on his part. As of December 17, 2002 (which is well past the requested reply date), no reply has been received from James H. Johnson.

Accordingly, Petitioner respectfully submits that requirements (4) and (5) have been satisfied with regard to James H. Johnson. Petitioner further contends that the foregoing description of the information provided in **Exhibits A and B**, together with the evidence offered in the previous Petitions (dated November 13, 2001 and April 22, 2002),

comprises sufficient evidence to show that a diligent effort has been made to secure the assistance of James H. Johnson in regard to the above-captioned patent application.

2. **John DiDomenico**

a. **Requirement (4): Proof that a copy of the application was sent or given to each of the non-signing inventors for review.**

Petitioner respectfully submits **Exhibit C** as evidence that a copy of the above-captioned application was sent to John DiDomenico for his review.

Exhibit C includes a copy of a package sent on November 12, 2002, via FedEx Priority Overnight delivery, to the last known address of John DiDomenico, at 8810 East Bear Paw Place, Tucson, Arizona 85749. The package included the following documents:

- Letter to John DiDomenico;
- Joint Declaration for Patent Application and Power of Attorney;
- Assignment;
- Copy of U.S. Patent Application Serial No. 09/840,080 titled: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR;" and
- Federal Express Return Envelope.

Also provided in **Exhibit C** are shipment tracking results indicating that a delivery attempt made on November 13, 2002 was successful.

b. **Requirement (5): Proof that each of the non-signing inventors refused to sign.**

The November 12, 2002 letter to John DiDomenico (shown in **Exhibit C**), specifically requested that Mr. DiDomenico respond within ten days of the date of receipt

of the package. The letter further stated that no reply on the part of Mr. DiDomenico would be considered a refusal to sign on his part. As of December 17, 2002 (which is well past the requested reply date), no reply has been received from John DiDomenico.

Accordingly, Petitioner respectfully submits that requirements (4) and (5) have been satisfied with regard to John DiDomenico. Petitioner further contends that the foregoing description of the information provided in **Exhibit C**, together with the evidence offered in the previous Petitions (dated November 13, 2001 and April 22, 2002), comprises sufficient evidence to show that a diligent effort has been made to secure the assistance of John Didomenico in regard to the above-captioned patent application.

CONCLUSION

On the basis of the foregoing, the Petitioner respectfully requests the granting of this Second Renewed Petition so that the application will be taken up promptly, and respectfully solicit favorable examination at that time.

Respectfully submitted,

MINTZ, LEVIN, COHN, FERRIS, GLOVSKY, AND POPEO, PC

By: _____
Bradford C. Blaise
Registration No. 47,429

Date: **December 17, 2002**

MINTZ, LEVIN, COHN, FERRIS, GLOVSKY, AND POPEO, PC
12010 Sunset Hills Road
Suite 900
Reston, Virginia 20190
(703) 464-4800 (Telephone)
(703) 464-4895 (Facsimile)

FedEx Express **USA Airbill**

FedEx Tracking Number **8371 3282 4772**

Form No. 0215 — SPH13 — **Sender's Copy**

1 From *Please print and press hard.*

Date 11-12-02 Sender's FedEx Account Number 2424-1865-4

Sender's Name BRADFORD BLAISE Phone (703)464-8130

Company MINTZ LEVIN COHN FERRIS GLOVSK

Address 12010 SUNSET HILLS RD

Dept./Floor/Suite/Room

City RESTON State VA ZIP 20190-5856

2 Your Internal Billing Reference First 24 characters will appear on invoice. OPTIONAL

3 To

Recipient's Name JAMES H. JOHNSON Phone ( )

Company

Address 4401 WEST CRESTFIELD ROAD

To "HOLD" at FedEx location, print FedEx address. We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address

Dept./Floor/Suite/Room

City TUCSON State AZ ZIP 85475

Try online shipping at fedex.com

By using this Airbill you agree to the service conditions on the back of this Airbill and in our current Service Guide, including terms that limit our liability.

Questions? Visit our Web site at fedex.com or call 1.800.Go.FedEx® 800.463.3339.

0224909413

4a Express Package Service — *Packages up to 150 lbs.* Delivery commitment may be later in some areas.

- [x] FedEx Priority Overnight — Next business morning
- [ ] FedEx Standard Overnight — Next business afternoon
- [ ] FedEx First Overnight — Earliest next business morning delivery to select locations
- [ ] FedEx 2Day — Second business day
- [ ] FedEx Express Saver — Third business day

FedEx Envelope rate not available. Minimum charge: One-pound rate

4b Express Freight Service — *Packages over 150 lbs.* Delivery commitment may be later in some areas.

- [ ] FedEx 1Day Freight* — Next business day
- [ ] FedEx 2Day Freight — Second business day
- [ ] FedEx 3Day Freight — Third business day

* Call for Confirmation:

5 Packaging — * Declared value limit $500

- [x] FedEx Envelope*
- [ ] FedEx Pak* — Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak
- [ ] Other

6 Special Handling — Include FedEx address in Section 3

- [ ] **SATURDAY Delivery** — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select ZIP codes
- [ ] **HOLD Weekday** at FedEx Location — NOT Available for FedEx First Overnight
- [ ] **HOLD Saturday** at FedEx Location — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations

Does this shipment contain dangerous goods? One box must be checked.

- [x] No
- [ ] Yes — As per attached Shipper's Declaration
- [ ] Yes — Shipper's Declaration not required
- [ ] Dry Ice — Dry Ice, 9, UN 1845 ____ x ____ kg

Dangerous Goods (including Dry Ice) cannot be shipped in FedEx packaging.

- [ ] Cargo Aircraft Only

7 Payment *Bill to:* — Enter FedEx Acct. No. or Credit Card No. below.

- [x] Sender — Acct. No. in Section 1 will be billed.
- [ ] Recipient
- [ ] Third Party
- [ ] Credit Card
- [ ] Cash/Check

FedEx Acct. No. / Credit Card No. Exp. Date

Total Packages	Total Weight	Total Declared Value†
		$ .00

†Our liability is limited to $100 unless you declare a higher value. See back for details. FedEx Use Only

8 Release Signature *Sign to authorize delivery without obtaining signature.*

Regina Walker

By signing you authorize us to deliver this shipment without obtaining a signature and agree to indemnify and hold us harmless from any resulting claims.

447

SRS • Rev. Date 4/02 • Part #157610S • ©1994–2002 FedEx • PRINTED IN U.S.A.

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- Email Track
- FedEx InSight
- Custom Critical
- Cargo Track
- FedEx Freight

Related Links
- Signature Proof
- My FedEx
- FedEx Wireless Solutions
- FedEx Address Checker

Track Shipments
Detailed Results

Quick Help

View detailed results for: Previous 837132824772

Est. Delivery Reattempt	11/13/2002 by 00:00
Tracking Number	837132824772
Reference Number	
Ship Date	11/12/2002
Delivered To	
Delivery Location	TUCSON AZ
Delivery Date/Time	
Signed For By	
Service Type	Priority Letter

Tracking Options
- Obtain a Signature Proof of Delivery
- Email these tracking results to one or more recipients
- Return to Summary Results
- Track More Shipments

Scan Activity	Date/Time	Comments
Delivery attemptTUCSON AZ	11/13/2002 10:07	Incorrect address
On FedEx vehicle for deliveryTUCSON AZ	11/13/2002 08:32	
Arrived at FedEx Destination LocationTUCSON AZ	11/13/2002 07:10	
Left FedEx RampTUCSON AZ	11/13/2002 06:10	
Left FedEx RampTUCSON AZ	11/13/2002 06:05	
Arrived at FedEx RampTUCSON AZ	11/13/2002 05:56	
Left FedEx Sort FacilityMEMPHIS TN	11/13/2002 03:42	
Left FedEx Sort FacilityMEMPHIS TN	11/13/2002 00:15	
Arrived at FedEx RampDULLES VA	11/12/2002 21:16	
Left FedEx Origin LocationRESTON VA	11/12/2002 20:58	
Picked up by FedExRESTON VA	11/12/2002 20:32	

Email Your Detailed Tracking Results

Enter your email (optional), up to three email addresses as recipients, add your message, and click on **Send Email**.

From

To

To

To

Add a message to this email.

Send Email

TUSA
TUSA
3601 E. COLUMBIA
TUCSON AZ 85714
(520)512-4500

SHIP DATE: 23NOV02

ACTUAL WGT: 1 LBS MAN-WT

TO: return
mintz levin cohn ferris glovsk
12010 sunset hills rd

reston VA 20190

4923 1711 9853 FedEx BILL RECIPIENT

4923 1711 9853

REF: 837132824772

EXPRESS SAVER WED

CAD# 0031349 23NOV02

TRK# 4923 1711 9853 Form 0201

Deliver by: 27NOV02 A1

153077 RIT 06/01

IAD

20190 -VA-US SA BCBA

ATTENTION

Customer

THIS SHIPMENT IS BEING RETURNED FOR THE FOLLOWING REASON(S):

___ Refused by recipient.
___ Recipient moved and left no forwarding address or phone number.
___ Recipient was not in when we attempted delivery and we were not authorized to leave the shipment without a signature.
X Recipient's address on your shipment was incorrect and/or incomplete and we were unable to obtain the correct address.
___ A Post Office box number was the only address given or obtainable.
___ Shipment held for pickup the maximum 5 days.
___ Unable to collect C.O.D. charges.
___ Shipper requested return.
___ Company policy does not allow us to keep an undeliverable shipment longer than 5 days.

OTHER: _____

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SEL68 5/99

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Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, P.C.

12010 Sunset Hills Road, Suite 900
Reston, Virginia 20190-5839

Bradford C. Blaise, Esq.

703 464 4800
703 464 4895 *fax*

Direct dial 703 464 8130
bcblaise@mintz.com

November 12, 2002

Via Federal Express **CONFIDENTIAL**

Mr. James H. Johnson
4401 West Crestfield Road
Tucson, Arizona 85475

Re: U.S. Patent Application
Serial No.: 09/840,080
Inventor(s): James H. Johnson, John DiDomenico
Title: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR"
Filed: April 24, 2001

Dear Mr. Johnson,

As you know, Envirotest Systems Corp. (ESP) has filed a series of patent applications for which you are a named inventor.

In particular, the above-referenced patent application is a continuation of 09/648,534 filed on August 28, 2000 (now abandoned), which is a continuation of 09/480,688 filed on January 11, 2000 (now abandoned), which claims priority from provisional patent application 60/115,537 filed on January 12, 1999.

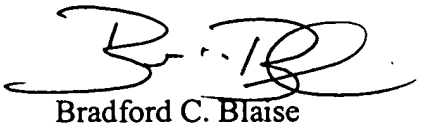
Moreover, the above-referenced patent application is identical to 09/648,534 and 09/480,688, meaning that all three applications comprise the same specification, drawings, and claims. A copy of the patent application that was filed for 09/840,080, 09/648,534, and 09/480,688 is enclosed.

Also enclosed are: (1) Joint Declaration and Power of Attorney; and (2) Assignment. At this time, we request that you execute the Declaration and Power of Attorney and Assignment documents, and return them to us as soon as possible for filing with the U.S. Patent and Trademark Office. For your convenience, I have enclosed a self-addressed Federal Express envelope for expeditious return.

Patent rights and the administrative procedures for securing patent rights are costly and time sensitive. Any delay on your part may generate additional expenses for ESP and could jeopardize the company's valuable patent rights. I also remind you of your continuing duty, pursuant to your former employment, to assist ESP in securing its rights. Accordingly, we request a response within ten (10) days from the date of this letter. If we receive no response from you within ten days we will consider it a refusal to sign.

If you have any questions regarding this matter, please do not hesitate to contact me at the telephone number listed above.

Very truly yours,



Bradford C. Blaise

BCB/mrs

Enclosures:

- Copy of U.S. Patent Application Serial No. 09/840,080 titled: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR," including drawing figures 1-6.
- Joint Declaration for Patent Application and Power of Attorney
- Assignment
- Federal Express Return Envelope

RES 77187v1

JOINT DECLARATION FOR PATENT APPLICATION

As the below named inventors, we hereby declare that:

Our residence, post office addresses and citizenship are as stated below next to our names;

We believe that we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled **REMOTE VEHICLE EMISSIONS SENSING DEVICE WITH SINGLE DETECTOR**, the specification of which

( ) is attached hereto.
(X) was filed on **April 24, 2001** as Application Serial Number **09/840,080** and was amended on

_____.
(if applicable)

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

Prior Foreign Application(s)

We hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Country	Application Number	Date of Filing (day, month, year)	Date of Issue (day, month, year)	Priority Claimed Under 35 U.S.C. 119
				Yes ☐ No ☐
				Yes ☐ No ☐

Prior United States Provisional Application(s)

We hereby claim the benefit under 37 C.F.R. §119(e) of any United States provisional application(s) listed below:

Application Number	Date of Filing (day, month, year)	Status - Patented, Pending, Abandoned
60/115,537	**12 January 1999**	

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
12010 Sunset Hills Road, Suite 900
Reston, VA 20190
703-464-4800
fax: 703-464-4895

Prior United States Application(s)

We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below, and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Number	Date of Filing (day, month, year)	Status - Patented, Pending, Abandoned
09/480,688	11 January 2000	Abandoned
09/648,534	28 August 2000	Abandoned

I hereby appoint the attorneys and/or agents associated with Mintz Levin Cohn Ferris Glovsky & Popeo,

Customer Number 
29315
PATENT & TRADEMARK OFFICE

to prosecute this application and to transact all business in the

Patent and Trademark Office connected therewith.

Please address all telephone calls to **James G. Gatto** at telephone number 703-464-4800

Please address all correspondence to: 
29315
PATENT & TRADEMARK OFFICE

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
12010 Sunset Hills Road, Suite 900
Reston, VA 20190
703-464-4800
fax: 703-464-4895

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature _____ Date _____

Full Name of Second Innventor	**JOHNSON** Family Name	**James** First Given Name	**H.** Second Given Name
Residence	**4401 W. Crestview Road, Tucson, Arizona 85475**		
Citizenship	**U.S.A.**		
Post Office Address	**Same as above**		

Signature _____ Date _____

Full Name of First Inventor	**DIDOMENICO** Family Name	**John** First Given Name	Second Given Name
Residence	**8810 East Bear Paw Place, Tucson, Arizona 85749**		
Citizenship	**U.S.A.**		
Post Office Address	**Same as above**		

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
12010 Sunset Hills Road, Suite 900
Reston, VA 20190
703-464-4800
fax: 703-464-4895

ASSIGNMENT

WHEREAS, **James H. Johnson,** a citizen of the United States of America, residing at **4401 West Crestfield Road, Tucson, AZ 85475**; and **John DiDomenico**, a citizen of the United States of America, residing at **8810 East Bear Paw Place, Tucson, AZ 85749** (hereinafter "Assignor" or "Assignors"), have made an invention entitled

REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR

described in the application for United States Letters Patent filed on April 24, 2001, and assigned **U.S. Application Serial No. 09/840,080**, which is a continuation of **U.S. Application Serial No. 09/648,534**, filed August 28, 2000 (now abandoned), which is a continuation of **U.S. Application Serial No. 09/480,688**, filed January 11, 2000 (now abandoned) and which claims priority to **U.S. Provisional Application Serial No. 60/115,537**, filed January 12, 1999; and

WHEREAS, **Envirotest Systems Corporation** (hereinafter "Assignee"), a Delaware corporation having a place of business at 11 Kripes Road, East Granby, Connecticut 06026, is desirous of acquiring the entire right, title and interest in and to the aforesaid invention, applications and all Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes and divisions which may be granted therefor;

NOW THEREFORE, in consideration of the sum of One Dollar ($1.00) and other good and valuable consideration, the receipt of which is hereby acknowledged, the said assignors, by these presents do sell, assign and transfer unto Assignee, its successors, legal representatives and assigns, the full and exclusive right in and to the said invention as described in the said application, and in and to any Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes and divisions which may be granted therefor and all rights to claim priority on the basis of said application;

AND WE HEREBY authorize and request the Commissioner of Patents and Trademarks or any other proper officer or agency of any country to issue all said Letters Patent to said Assignee;.

AND WE HEREBY warrant and covenant that we have the full right to convey the entire interest herein assigned and that we have not executed and will not execute any instrument or assignment in conflict herewith;

AND WE HEREBY authorize any attorney and/or agent of Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, PC, to insert any information necessary to ensure that this Assignment is complete upon submission to the United States Patents and Trademark Office;

AND WE HEREBY agree to communicate to said Assignee or its representatives any facts known to us respecting said invention, to execute all divisional, continuation, reissue, reexamination, extension, substitute and foreign applications, sign all lawful documents and make all rightful oaths and declarations relating to said invention, execute and deliver any and all papers that may be necessary or desirable to perfect the title to this invention in said Assignee, its successors, legal representatives or assigns, and to testify in any judicial or administrative proceeding and generally do everything possible to aid the said Assignee to obtain and enforce said Letters Patent in the United States or any foreign country when requested so to do by said Assignee.

Signature of Inventor: _____

Inventor's Name: **James H. Johnson**

Date of Execution: _____

IN WITNESS WHEREOF, I have hereunto set my hand and seal.

County of)
) ss:
)

On this _____ day of _____, 2002, before me a Notary Public in and for the County and State aforesaid, personally appeared **James H. Johnson**, to me know to be the person whose name is subscribed to the within instrument and acknowledged that he executed it of his own free act and deed.

(SEAL)

_____
Notary Public

My commission expires: _____

Signature of Inventor: _____

Inventor's Name: **John DiDomenico**

Date of Execution: _____

IN WITNESS WHEREOF, I have hereunto set my hand and seal.

County of)
) ss:
)

On this _____ day of _____, 2002, before me a Notary Public in and for the County and State aforesaid, personally appeared **John DiDomenico**, to me know to be the person whose name is subscribed to the within instrument and acknowledged that he executed it of his own free act and deed.

(SEAL)

_____
Notary Public

My commission expires: _____

REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR

Field of the Invention

The present invention relates generally to filter/detector arrangements for use in remote vehicle emissions analysis and remote sensing devices.

Background of the Invention

Remote sensing devices may be used to detect and characterize emissions from a vehicle. One device for performing such a process analyzes radiation that passes through the vehicle emission using a detector. Various components of the vehicle emission absorb radiation of specific characteristic wavelengths. A filter is used to permit only a radiation band including the characteristic wavelength of interest to reach the detector. If multiple components of the emission are to be analyzed in this manner, multiple sets of detectors and filters are generally necessary to carry out such measurements.

A known device for the remote sensing of vehicle emissions is depicted in Fig. 1. A beam (1) from a radiation source (7) passes through emissions plume (8) of vehicle (9) and is reflected from mirror (2) onto reflecting wheel (3). Beam (1) is then reflected from reflecting wheel (3) to one of a group of mirrors (4). The group of mirrors (4) focus and reflect the beam (1) through

respective filters (5) and onto respective detectors (6). One such remote sensing device is disclosed in U.S. Patent No. 5,210,702.

Such devices, however, may have certain drawbacks. These devices may have a large number of parts to manufacture, assemble, align, maintain, and calibrate, including special reflectors, multiple detectors and multiple light filters. Each of these parts introduces error into the final measurements. For example, light filters may suffer from light bleed, allowing undesirable wavelengths of light to reach the detectors. Uncertainty as to the measurements may also occur because different detectors may react differently to the variety of conditions encountered during the use of these devices.

Additionally, use of multiple filters, detectors, reflectors, and the like can add considerable complexity and bulk to the device. Also, if other components of the emission are to be detected, the replacement of filters and/or detectors to provide suitable filters and detectors for such other components may involve considerable cost in parts, as well as in assembly, alignment, and calibration of the device.

Another gas analysis device is disclosed in U.S. Patent No. 4,678,914. This device employs an infrared (IR) gas analyzer in which IR radiation from a source is directed toward an IR detector. The IR radiation passes through both a gas located in a sample cell and then one of various light filters mounted on a continuously rotating filter wheel. This device requires close proximity to an emissions output in order to operate properly, and employs a sample chamber for gas analysis. Devices which employ a gas sample chamber are not feasible

for remote sensing of vehicle emissions because of the need to collect a sample of the emission and isolate it in the gas sample chamber. Also, such devices only provide a localized reading of the gas at the exact point where the sample is taken.

These and other drawbacks of known devices exist.

Summary of the Invention

An object of the present invention is to overcome these and other drawbacks in existing devices.

Another object of the present invention is to provide greater flexibility in remote vehicle emissions sensing devices by allowing multiple different components to be detected without using multiple detection units.

Another object of the present invention is to provide greater accuracy and certainty in remote vehicle emissions sensing devices by reducing the number of detectors used in such devices to thereby reduce uncertainty caused by use of several different detectors under changing ambient conditions.

One aspect of the present invention provides a device including a radiation source, a detector, and a plurality of filters. A beam from the radiation source passes through the emission plume of a vehicle, and one of the plurality of filters which is aligned with the detector to the detector. When a different component of the emission is to be analyzed, the filter which is aligned with the detector is changed and the detection process is repeated.

Another aspect of the invention provides a method for remotely sensing vehicle emissions by passing a beam from a radiation source through a vehicle emission plume and one of a plurality of filters which is aligned with a detector to the detector. The method may also include the step of moving the filters to align different filters with the detectors or moving the detector to allow the detector to be aligned with different ones of the filters.

Other aspects and advantages of the invention will be apparent from the detailed description of the preferred embodiments which follows.

Brief Description of the Drawings

Fig. 1 illustrates a known remote vehicle emissions sensing device.

Fig. 2a illustrates an embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 2b illustrates another embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 3 illustrates a wheel with filters mounted thereon which may be employed in accordance with the present invention.

Fig. 4 illustrates moveable filters and a detector located in a sealed housing according to another embodiment of the present invention.

Fig. 5 illustrates another embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 6 shows a schematic block diagram of the components of an embodiment of a remote vehicle emission sensing device in accordance with the present invention.

Detailed Description of the Preferred Embodiments

The present invention, as illustrated in Figs. 2a and 2b, is intended for use in a system for the remote sensing of vehicle emissions, whereby a variety of different components of the vehicle emission are sensed by passing a beam of radiation through the vehicle emission plume. After passing through the emission plume, the beam, which may include ultraviolet radiation and/or infrared radiation, is received by a detector. The concentrations of various components of the vehicle emission plume may be calculated by determining the amount of radiation of certain characteristic wavelengths which has been absorbed from the beam by the emission components of interest upon passage through the vehicle emission plume.

Fig. 2a illustrates one embodiment of a remote sensing device ("RSD") in accordance with the present invention. A beam (11) from a radiation source (10) passes through an emission plume (12) of a vehicle (16). The beam (11) may optionally be focused on a detector (14) by lens (13). The light beam (11) also passes through a set of moveable filters (15) before it impinges on detector (14).

In the present invention, moveable filters (15) allow a single detector (14) which has a broad enough frequency response to cover all of the detection

bands of interest, to measure different components of the vehicle emission plume. Alternatively, two or more detectors (14) can be employed to cover all of the detection bands of interest. Each filter (15) permits only a certain detection band of radiation to reach the detector (14). Filters (15) may be pass through filters, which allow transmission of only certain wavelengths through the filters (15). Each of the various filters (15) is used to isolate different detection bands of radiation for detection of different components of the vehicle emission. Each detection band is carefully selected to be centered about a wavelength of radiation that is characteristic of the absorption pattern of a specific component of the vehicle emission. In this manner, radiation characteristic of each component of the vehicle emission can be isolated and impinged at different times upon the same detector (14).

The filters (15) may be moved so that one filter (15) at a time is aligned with only a single detector (14). The alignment is such that all radiation to be received by the detector (14) must first pass through the aligned filter (15). A single RSD may be employed to detect multiple components of a vehicle emission without requiring more than one detector (14) because the present invention allows a plurality of different detection bands to be directed to a single detector (14) using a moveable set of filters (15).

In another embodiment shown in Fig. 2b, a movable set of reflective filters (17) is used. A beam (11b) from a radiation source (10b) passes through an emission plume (12b) of a vehicle (16b). The beam (11b) may optionally be focused on a detector (14b) by lens (13b) via reflection off of one or more of a

moveable set of reflective filters (17). Reflective filters (17) may reflect only the wavelengths of specific detection bands of radiation for detection of different components of vehicle emission plume (12b)

In an embodiment shown in Fig. 3, the moveable set of filters (23) may comprise a rotating filter wheel with filters mounted on the wheel. As illustrated in Fig. 3, the filter wheel (21) is mounted for rotation about its axis (22). Various filters (23) are mounted on the filter wheel (21). Thus, in this embodiment, the filter wheel (21) may be rotated on its axis to align different filters (23) with a single detector at different times. As noted previously, each filter (23) permits only a specific detection band of radiation to reach the detector by transmission or reflection. Each detection band is centered on a wavelength of radiation that is characteristic of the absorption pattern of a specific component of the vehicle emission. Each filter (23) on the wheel (21) passes a detection band of radiation which corresponds to a specific vehicle emission component to be detected. The wheel (21), and therefore the filters (23), rotate so that multiple vehicle emission components may be sequentially detected and analyzed using a single detector.

The filter wheel (21) may be provided with a plurality of notches (24) which may periodically activate an optical switch (not shown) whereby the processor (19) can associate a particular detector reading with a particular one of filters (23) so that the reading can be linked to the component of the exhaust being measured. Any other suitable means for informing the processor (19) which filter (23) is associated with a particular detector reading may be

employed. For example, the filter wheel (21) may be rotated stepwise and for each step of rotation a signal may be sent to the processor.

Preferably, one of the filters (23) corresponds to a reference channel having a transmission bandwidth centered at a wavelength of 3.9 microns. This reference channel can be employed to determine background noise and/or exhaust opacity, if desired.

In another embodiment of the invention shown in Fig. 4, moveable filters (41) and a detector (42) are placed in a sealed housing (43). By placing moveable filters (41) and a detector (42) in a sealed housing (43), undesired radiation may be prevented from impinging on the detector (42) or entering the filters (41). The sealed housing (43) may have, for example, a single opening (44) to allow a beam (45) from a source (47) to enter after passing through vehicle emissions plume (48) of vehicle (49). As illustrated in other embodiments, a focusing mirror (46) may be used to focus beam (45) onto the detector (42). Moveable filters (41) and a detector (42) may be aligned in such a manner as to receive beam (45) at the detector (42) through a single one of filters (41).

In another embodiment of the invention, a general filter (50) may be placed in the path before the detector to prevent unwanted radiation from reaching the detector. A general filter (50) may be used, for example, to eliminate radiation outside a broad detection band which includes radiation of wavelengths within a series of narrower detection bands specific to each of the components of interest. The general filter (50) may alternatively be employed

to filter out specific radiation components such as all visible light, all ultraviolet light, etc. In one embodiment of the invention, a beam from the radiation source includes radiation having wavelengths in the broad detection band of 3 to 6 microns, and a general filter (50) may be configured to prevent all other light from reaching the detector (42) and/or the filters (41). Thus, a general filter (50) may be placed at the single opening (44) of a sealed housing (43). Movable filters (41) are then aligned so that a beam (45) impinging on the detector (42) passes through a desired one of filters (41) before reaching the detector (42).

Other embodiments of the invention are also envisioned. In a further alternative embodiment (not shown), the moveable filters (41) slide into alignment with the detector (42). In another embodiment, the filters are stationary, and the detector (42) may be moved to align it with the appropriate filter. As illustrated in Fig. 5, a beam (52) from radiation source (51) passes through a vehicle emission plume (53) of a vehicle (53a). Beam (51) reflects off of mirror (54) onto reflecting wheel (55). Reflecting wheel (55) directs beam (51) through respective focusing lenses (56) to focus the beam (51) through filters (57) and onto detector (58). Detector (58) is moveable in slot (59) so that it may be aligned with the appropriate one of filters (57). Other variations on this embodiment of the invention are also possible.

A method of remotely sensing vehicle emissions is also contemplated in the present invention. Using the structure of the present invention, vehicle emissions may be sensed by emitting radiation from a radiation source and

passing the radiation through a vehicle emission plume. The method is continued by passing radiation through one of a plurality of filters, receiving the radiation at a detector, and determining the concentration of one or more components of the vehicle emissions from the detector response.

As noted previously, the filters may be located on a wheel mounted for rotation about its central axis. In one embodiment of the invention, the wheel rotates at a constant speed. In another embodiment of the invention, the wheel only rotates when a vehicle emission plume is present in the light beam.

The present invention improves on known devices by eliminating the need for multiple sets of filters and corresponding detectors, and reducing the number of parts needed. Use of moveable filters or a moveable detector may eliminate the need for multiple detectors, (6), multiple mirrors, (4), and a reflecting wheel, (3), which are employed in the conventional device shown in Fig. 1. Additionally, multiple vehicle emission components may also be determined without having to align a reflecting wheel (3), multiple mirrors (4), multiple filters (5), and multiple detectors (6). As illustrated in Fig. 2, the beam (11) may be directed through one of the moveable filters (15) which is currently aligned with the detector (14). This saves time, effort, and expense when manufacturing and repairing the RSD. Additionally, filter wheel (15) may be easily changed, thus allowing a series of different components in the vehicle emission to be detected by providing a series of new filters which permit passage of radiation within the appropriate detection bands for the different components.

The RSD of the present invention allows detection of vehicle emissions in an open area. There is no need for a cell or chamber in which to gather the emission plume to determine the concentrations of various components thereof. Further, this configuration allows a single RSD of the present invention to sequentially sense the vehicle emissions of multiple vehicles over a short time span to thereby make remote roadside vehicle emission sensing practicable.

Further, the RSD unit of the present invention may be a mobile RSD which is capable of being moved to a number of locations. In one embodiment, the RSD is placed at an exit ramp of a highway, and is used to remotely determine components of vehicle emissions. Some time later, the RSD may be moved to a different location and employed at the new location to sense the same or different components of vehicle emissions.

Fig. 6 illustrates a schematic representation of components of a RSD in which the present invention may be employed. Embodiments of the invention may include some or all of the various components as described below.

Radiation Source

Preferably, an RSD unit comprises a source of electromagnetic radiation 10 which may be used in the absorption spectroscopy measurement of vehicle exhaust emissions. Preferably, source 10 may comprise an infrared (IR) radiation source producing beam 11. Some embodiments of the RSD may include other types of radiation sources, for example, an ultraviolet (UV) source, a visible light source, or a combination of sources.

Radiation Detector

The RSD unit may further comprise a detector 12 of electromagnetic radiation. The detector 12 is preferably chosen to permit detection of electromagnetic radiation emitted by the source. For example, the detector 12 may comprise a photodetector (*e.g.*, a photodiode), a photomultiplier tube (PMT), a spectrometer or other suitable radiation detector. For embodiments using ambient radiation sources an appropriately sensitive detector may be used. For example, a mercury cadmium telluride (Hg Cd Te) photodetector may be used to detect ambient IR radiation. Other detectors are possible.

Reflector

According to one embodiment, the RSD unit may comprise a reflector 14 mounted in a manner to allow radiation from the source 10 to be reflected into the detector 12 for analysis. The reflector 14 may comprise a mirror, prism, diffraction grating, beam splitter or other device suitable for reflecting the radiation of the source 10. The reflector 14 may form part of the detection unit in which case the reflector 14 may function to split the radiation beam among one or more detectors, focus the radiation beam onto one or more detectors or redirect the radiation beam to the appropriate detection for detection of a particular species. In addition, plural reflectors 14 may be employed to accomplish one or more of these functions in any combination.

In another embodiment the reflector 14 may comprise a lateral transfer mirror used to reflect the source 10 radiation back along a path displaced laterally (or vertically) from the path between source 10 and reflector 14. In

this embodiment, the reflector generally does not form part of a detection unit but rather is located remotely from the detection unit. The primary purpose of transfer mirrors is to redirect the radiation to the detector unit. A variety of different transfer mirrors may be employed in the RSD unit depending primarily upon the particular spatial relationship of the radiation source 10, detector 12 and reflector 14 which is to be employed by the RSD unit. Several configurations are described below, some of which require different types of transfer mirrors to redirect the radiation beam to the detector unit.

Imaging Unit

The RSD unit may also include an imaging unit 16 which may be used to capture or record an image of a vehicle passing through the detection system. The imaging unit 16 may be arranged to record an image of a vehicle at a specified location in the detection system. The imaging unit 16 may comprise, for example, a camera, such as a film, video or digital camera. Other imaging devices may also be used.

Preferably, the imaging unit 16 may record an image of the vehicle identification tag (*i.e.*, license plate). Tag information may be processed, using a suitable data processor, to identify additional information about the respective vehicle. For example, Motor Vehicle Department databases may be accessed to retrieve vehicle owner information, vehicle make, model type, model year and other information. In some embodiments, this additional information may be incorporated into the emission sensing data analysis. For example, the make and model year of the vehicle may be used to input information (*e.g.*, whether

the vehicle includes a carburetor or fuel injector, etc.) into certain data processing routines.

Speed and Acceleration

The RSD unit may also include a speed and acceleration detection unit 18. Preferably, a vehicle's speed and acceleration through the detection system may be measured using speed detection unit 18. For example, the speed detection unit may comprise an arrangement of laser beams associated with timing circuitry. The arrangement of laser beams may be arranged to traverse the path of a vehicle at various points in the detection system. As a vehicle passes through the detection system it will cause interruptions in the laser beams. The times at which the beam interrupts occur may be used to calculate the vehicle's speed and acceleration. Other methods of detecting vehicle speed and acceleration may also be used. For example, radar systems or transducers (or piezoelectric elements) may be placed at locations in the roadway to monitor vehicle passage through the system. Preferably, the speed and acceleration data may be input into a data processing unit 19 to accurately characterize vehicle operation conditions (*e.g.*, accelerating or decelerating). Other uses of the speed and acceleration data are also possible.

Thermal Detection Unit

Some embodiments of the invention may incorporate a thermal detection unit 20. Preferably, the thermal detection unit 20 may comprise a non-contact thermometer system. For example, an IR thermometer may be

used to optically detect the temperature of remote objects. Other temperature detection systems may also be used.

Preferably, the thermal detection unit is used to detect the temperature of portions of the vehicle passing through the RSD system. Some embodiments may use direct sensing of the area of interest. For example, an IR thermometer may be aimed at the underside of a passing vehicle to detect the temperature(s) of vehicle components (*e.g.*, engine, catalytic converter, muffler, etc.). Indirect sensing may also be used. For example, an IR thermometer may be aimed at the roadway to measure the heat reflected from the underside of a vehicle.

Preferably, the thermal information recorded by the thermal imaging unit 20 may be incorporated into the processing for the vehicle emission data. For example, a temperature reading of a vehicle's engine may indicate that the engine has just recently been started (*i.e.*, the engine is "cold" or has not reached normal operating temperature). Such a cold engine reading may initiate alternative data processing for the emission data.

Data from thermal detection unit 20 may also be used for other data handling procedures. For example, it may be preferable to identify whether a vehicle's catalytic converter is operational. A temperature reading indicating that the catalytic converter is "cold" may indicate that the converter is not functioning. However, a cold catalytic converter might also indicate that the vehicle has only been driven for a short period and, thus, has not achieved operational temperature. Embodiments of the present invention reduce the chance of such a potentially misleading reading by detecting the temperature of

other portions of the vehicle. For example, a temperature reading indicating that the catalytic converter is cold, but the brake rotor (or engine) is "hot" indicate, with greater certainty, that the vehicle has reached operating temperature and the catalytic converter is indeed non-operational. Other uses for collected thermal data are also possible.

Thermal detection unit 20 may comprise various detection apparatus configurations. For example, two thermal detectors may be arranged to view a vehicle traveling in a traffic lane. Preferably, the thermal detectors are positioned at points affording different angles of view at the vehicle. The thermal detectors may be positioned near the locations of speed and acceleration detection units (*i.e.*, spaced with some distance between detectors). Spatial separation of the detectors and use of differing angles of view increase the likelihood of detecting the temperature of the areas of interest on the vehicle (*e.g.*, the engine, catalytic converter, etc.) and also afford a time sequence of measurements (*i.e.*, the vehicle crosses one detector, then the other at a later time). In some embodiments, an additional thermal detector may be incorporated. The additional thermal detector may be positioned at a suitable location to detect the temperature of the front of the vehicle (*e.g.*, the radiator or engine). For example, the additional thermal detector may be positioned at either side of the lane at a sufficient height to detect the front of the vehicle, or be embedded into the lane to record a head-on view of the vehicle.

Some embodiments may include arrays of thermal detectors to achieve an even greater likelihood of detecting the desired temperature readings. For

example, in an embodiment incorporating an IR thermometer, an array of detection beams may be aimed at the vehicle. The array may span vertical and horizontal regions. Using such an array of detection beams allows the thermal detection unit 20 the ability to detect the temperature of vehicles of varying size and shape. In addition, some of the beams in the array may be used to detect reflected heat off of the lane. Using an array of detector beams may also result in greater accuracy in temperature measurements. The focal point of each detection beam in the array can be narrowed to detect the temperature of a smaller region of interest. In this manner, a more accurate temperature of each point may be obtained. For example, a detector beam with a focal point four inches in diameter will take an average temperature over the whole four inch region within the focal point. If the region of interest happens to be a one inch exhaust pipe on a vehicle, the detector will average the temperature of the region of interest (*i.e.*, the pipe comprising one-fourth of the focal region) with objects outside of the region of interest (*i.e.*, the other three fourths of the focal region) resulting in a less accurate temperature reading. In contrast, an array of smaller focal point detector beams (*e.g.*, one inch in diameter each) will be more likely to detect an accurate temperature of the region of interest (*e.g.*, a one inch exhaust pipe).

These and other thermal detection techniques may be used advantageously in a remotely operated unit, but are not limited to such use. They may also be used in other RSD systems as well.

Processing Unit

The RSD unit preferably includes a data processing unit 19 to carry out analysis of detected data, among other things. The processing may be accomplished using a suitable processing device, for example, a computer or other microprocessor. The processing unit 19 may include software to accomplish desired analysis of collected data. For example, the software may be used to calculate the concentrations of various exhaust gas constituents (*e.g.*, HC, CO_2, NO_x, CO, etc.), the decay rate (*e.g.*, dissipation in time) of the exhaust constituents, the opacity of the exhaust plume, the temperature, speed and acceleration of the vehicle, and other calculations. In one embodiment, software may be used to calculate detected ratios between CO_2 and other exhaust components. The software may make comparisons to threshold concentration values or emission profiles for characterization of vehicles as high or low emitting vehicles and to ensure compliance with predetermined emission standards.

The processing unit may also comprise software routines to accomplish other data analysis functions. For example, the vehicle emission data may be checked for running losses. Running losses may typically include emission readings due to fuel system leaks on a vehicle (*e.g.*, leaky fuel tank filler cap, fuel line, etc.), blow by emissions (*i.e.*, emissions due to other vehicles in the vicinity) or other systematic losses.

The data processing may also include software routines to accomplish various vehicle owner notification processes. For example, a vehicle owner of

a vehicle that has been recorded as "clean" (*i.e.*, in compliance with certain predetermined emission levels) may, upon a second recording of "clean," receive notification of the fact. Coordination with local authorities may be arranged to grant vehicle owners a waiver or pass of local emission certification procedures upon receiving such clean notification. Likewise, owners of vehicles that fail to meet predetermined emission levels may receive notification requiring the owner to remedy the non-compliance. Other data processing functions are possible.

Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. The specification and examples should be considered exemplary only. The scope of the invention is to be determined by the claims appended hereto.

Claims

What is claimed is:

1. --A gas analysis device for remotely determining at least one characteristic of a vehicle emission plume comprising:

a radiation source;

a plurality of moveable filters sequentially positionable to receive radiation from said radiation source after the radiation has passed through a vehicle emission plume, each of said filters being capable of filtering out radiation except for a predetermined wavelength band; and

a detector positioned such that radiation from said radiation source may be sequentially directed onto said detector via at least two filters to thereby produce a plurality of detector responses proportional to the intensity of radiation directed onto the detector via said at least two filters.

2. The device according to claim 1, wherein said plurality of filters are arranged on a moveable filter wheel.

3. The device according to claim 2, wherein the filter wheel and the detector are housed in a housing which is sealed to substantially prevent radiation from reaching the detector except via one of said filters.

4. The device according to claim 1, further comprising a general filter which removes substantially all visible light from a radiation beam passed through said general filter, said general filter being positioned such that a beam from said radiation source must pass through said general filter after passing through a vehicle emission plume and before reaching said detector.

5. The device according to claim 1, wherein said plurality of filters comprise at least one reflective filter.

6. The device according to claim 1, wherein said plurality of filters comprise at least one pass through filter.

7. The device according to claim 1, wherein said radiation source projects a beam of infrared radiation across the path of a moving vehicle.

8. The device according to claim 1 further comprising a processor for processing at least one detector response to provide information about the composition of an exhaust plume of a moving vehicle.

9. The device according to claim 8 further comprising an indicator for informing the processor which filter is optically aligned with the detector for a particular detector response.

10. A method for remotely determining at least one characteristic of a vehicle emission plume comprising the steps of:

a) providing a source of radiation and a plurality of filters each of which is capable of filtering out radiation except for radiation in a predetermined wavelength band;

b) directing radiation from the source through an emission plume of a moving vehicle to a first filter and then to a detector;

c) generating a first detector response indicative of the intensity of radiation received by the detector;

d) positioning a further filter such that the radiation from the source is directed through the exhaust plume of the moving vehicle to the further filter and then to the detector;

e) generating a further detector response indicative of the intensity of light received by the detector via the filter positioned in step d);

f) optionally repeating a sequence of steps d) - e) to obtain an additional detector response for each repetition of the sequence; and

g) determining at least one characteristic of the vehicle emission plume from said detector responses.

11. The method according to claim 10, wherein the plurality of filters are arranged on a filter wheel, and the step of moving the plurality of filters comprises rotating the filter wheel.

12. The method according to claim 10, further comprising the step of passing the radiation from the emission plume through a general filter to remove substantially all light having a wavelength outside a predetermined broad detection band prior to directing said radiation to the plurality of filters.

13. The method according to claim 10, wherein the plurality of filters and the detector are located within a housing which is sealed to substantially prevent radiation from reaching the detector except via one of said filters.

14. The method according to claim 10, wherein the source of radiation directs the radiation through the emission plume.

15. The method according to claim 14, wherein the source of radiation directs a beam of infrared radiation across the path of a moving vehicle.

16. The method according to claim 10, wherein the filters comprise at least one pass through filter.

17. The method according to claim 10, wherein the filters comprise at least one reflective filter.

18. A method for remotely determining at least one characteristic of a vehicle emission plume comprising the steps of:

a) providing a source of radiation and a plurality of filters each of which is capable of filtering out radiation except for radiation in a predetermined wavelength band;

b) directing radiation from the source through an emission plume of a moving vehicle to a first filter and then to a detector;

c) generating a first detector response indicative of the intensity of radiation received by the detector;

d) positioning the detector such that the radiation from the source may be directed through the exhaust plume to a further filter and then to the detector;

e) directing the radiation from the source to the filter positioned in step d) and then to the detector;

f) generating a second detector response indicative of the intensity of light received by the detector via the further filter;

g) optionally repeating a sequence of steps d) - f) to obtain an additional detector response for each repetition of the sequence; and

h) determining at least one characteristic of the vehicle emission plume from said detector responses.

19. The method according to claim 18, wherein the filters comprise at least one pass through filter.

20. The method according to claim 18, wherein the filters comprise at least one reflective filter.

Abstract of the Disclosure

A remote sensing device for determining at least one characteristic of a vehicle emission plume includes a radiation source, a detector, and a plurality of filters. Either the filters or the detector are movable relative to the other such that different filters, each of which is capable of filtering out radiation except radiation of a predetermined wavelength band, can be used to filter the radiation directed to the detector. Also disclosed is a method for remotely determining at least one characteristic of a vehicle emission plume using a single detector and a plurality of filters wherein either the detector or the filters are positionable relative to one another.

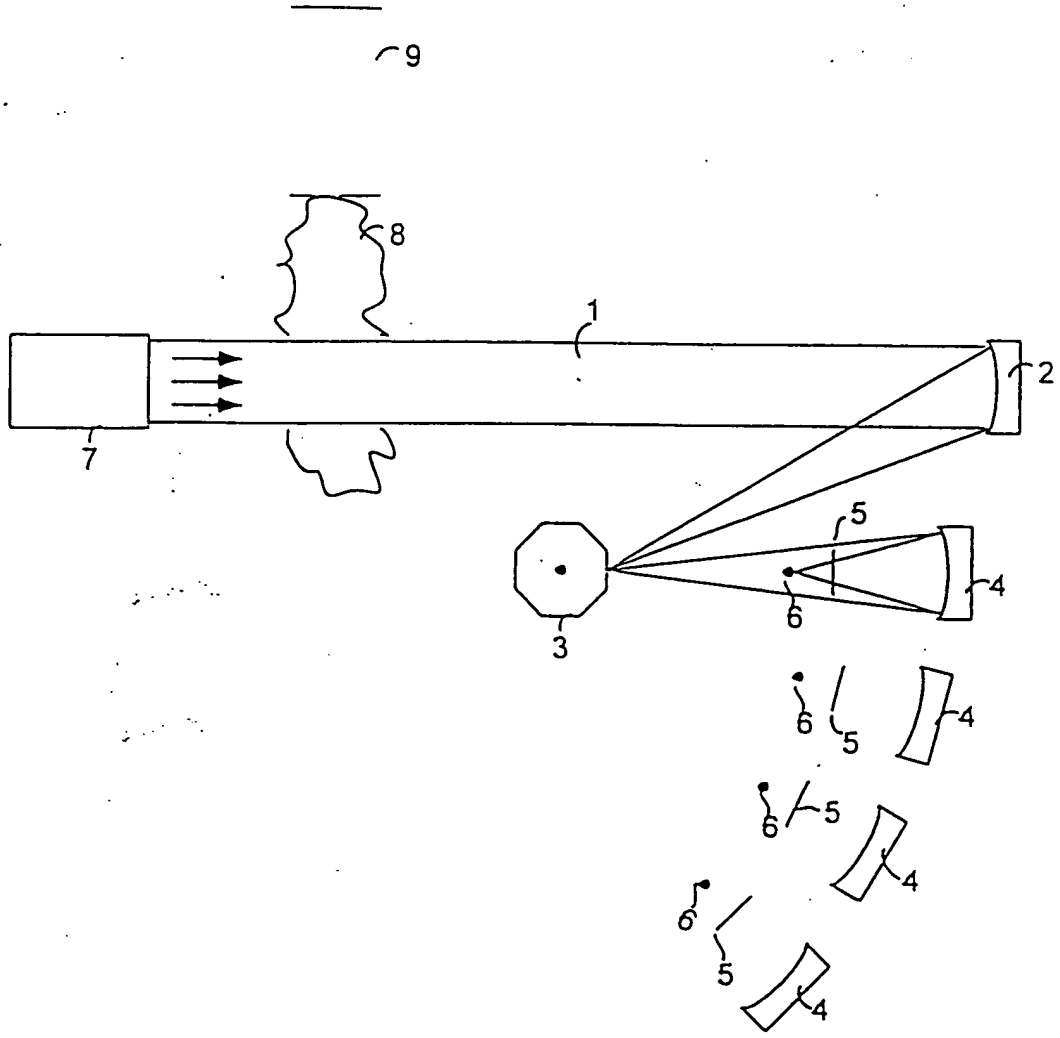


Fig. 1

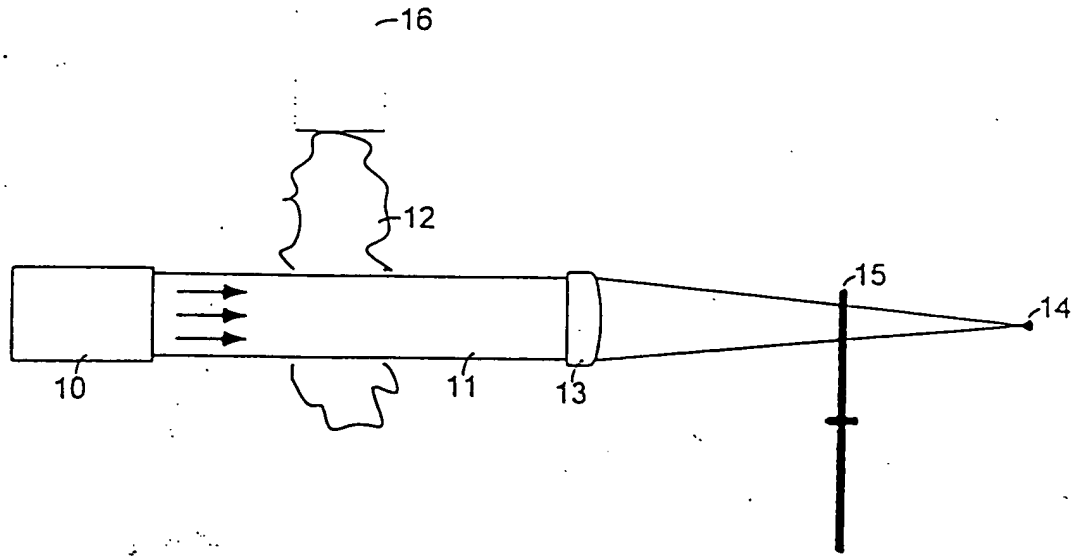


Fig. 2a

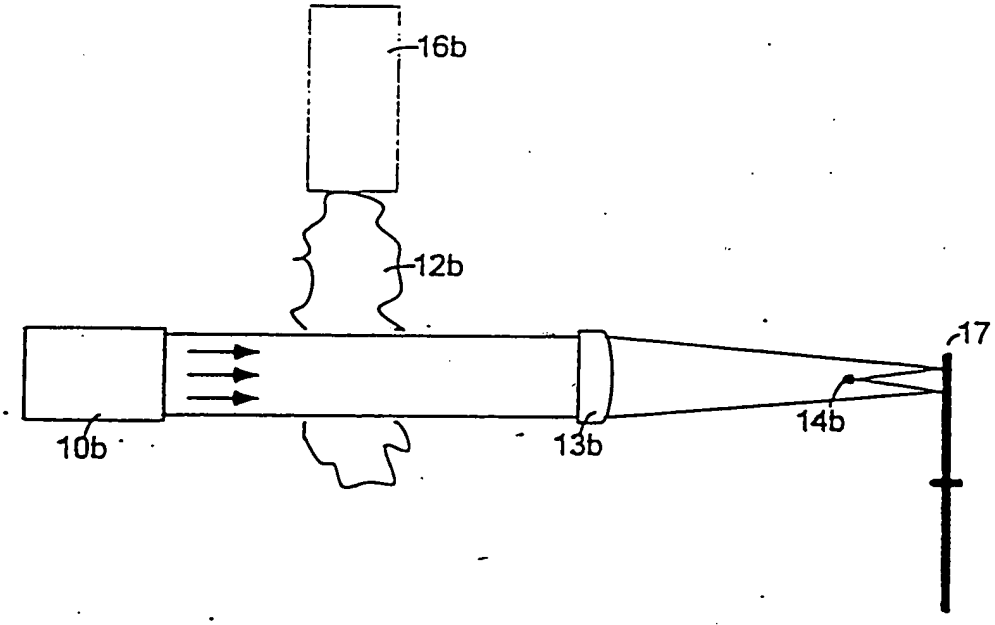


Fig. 2b

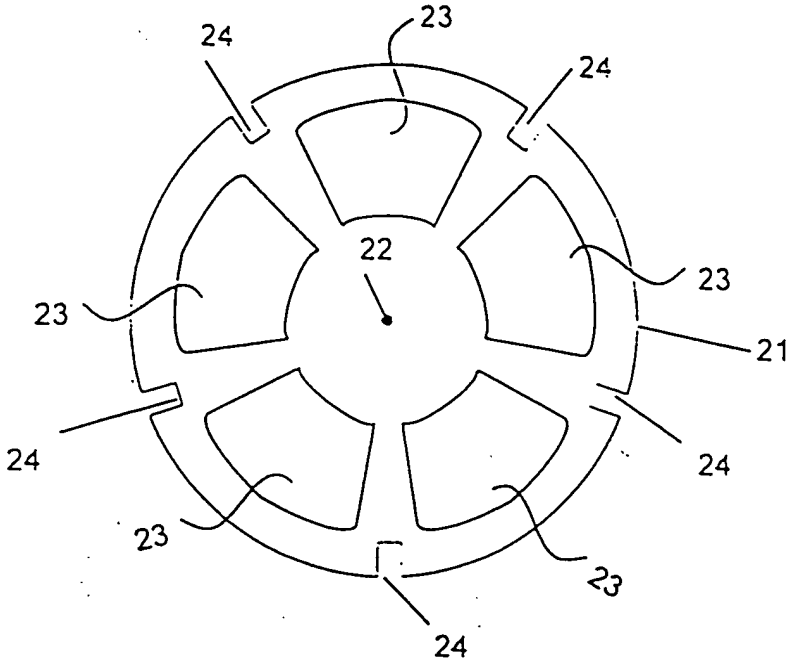


Fig. 3

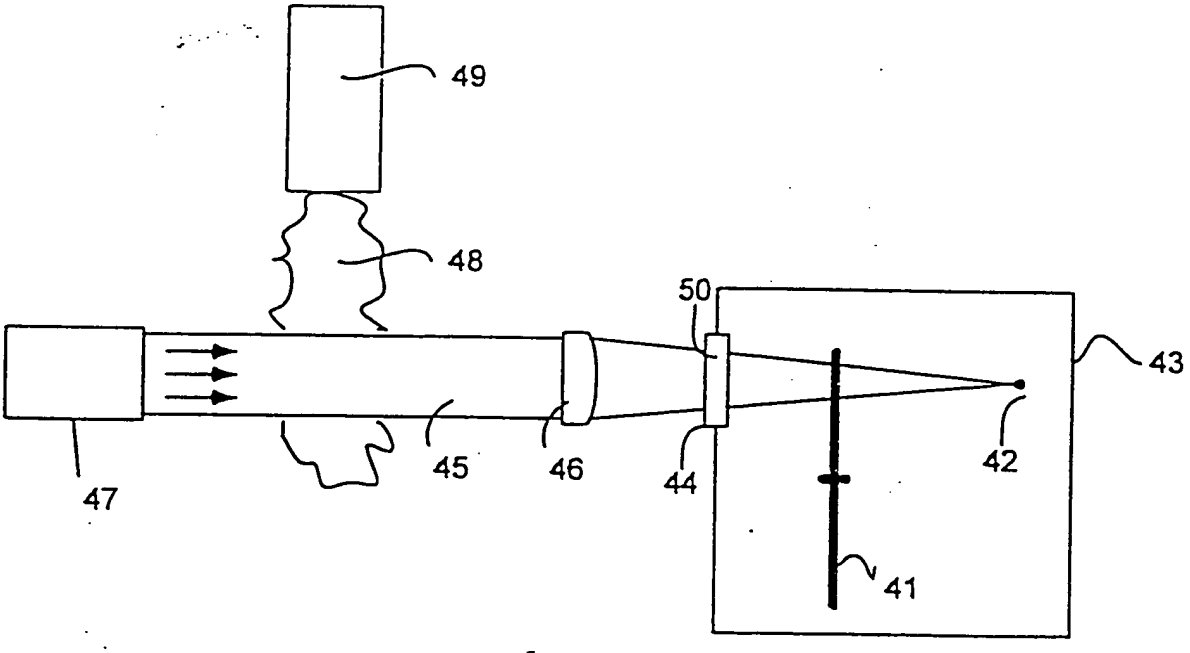


Fig. 4

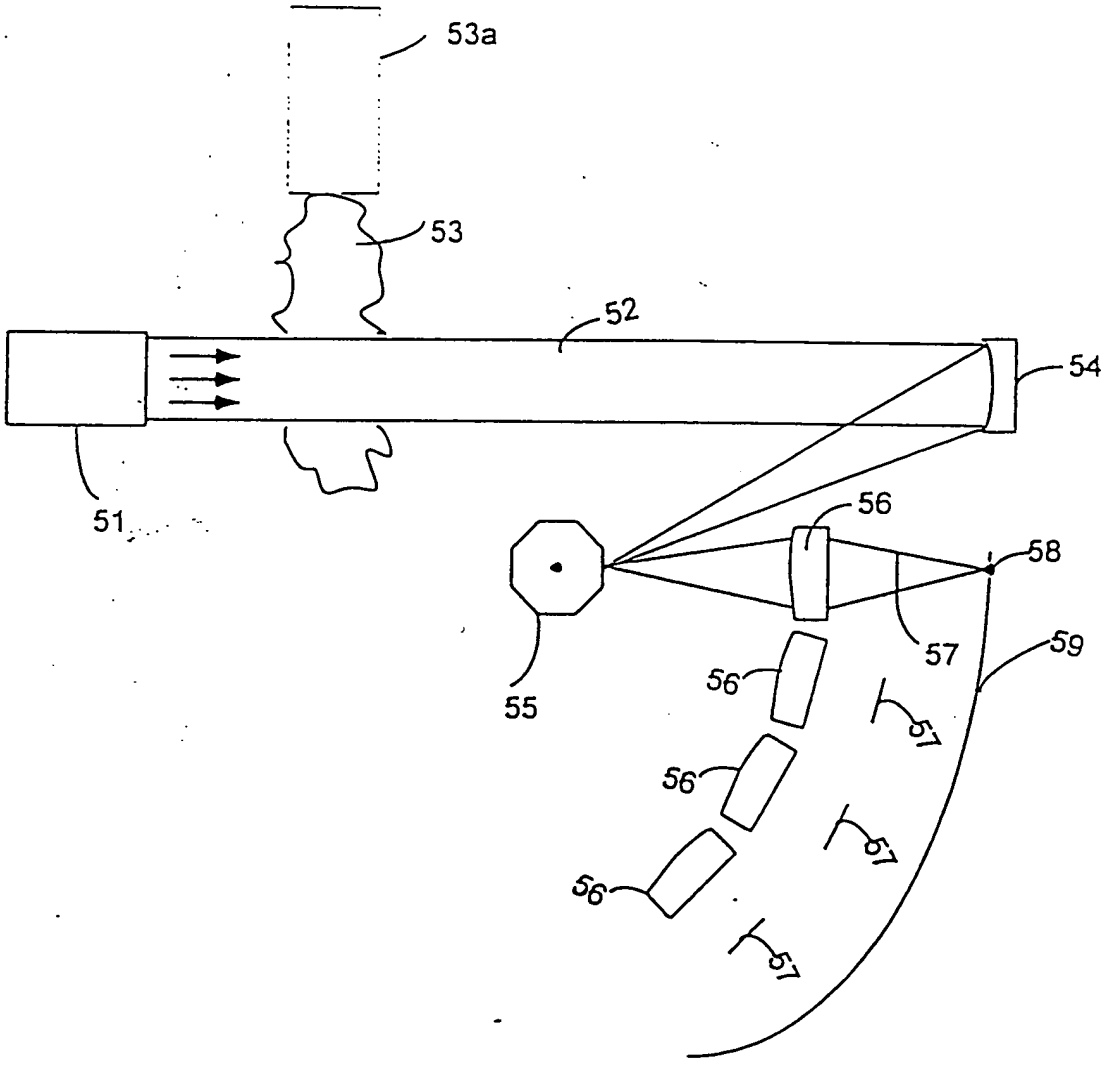


Fig. 5

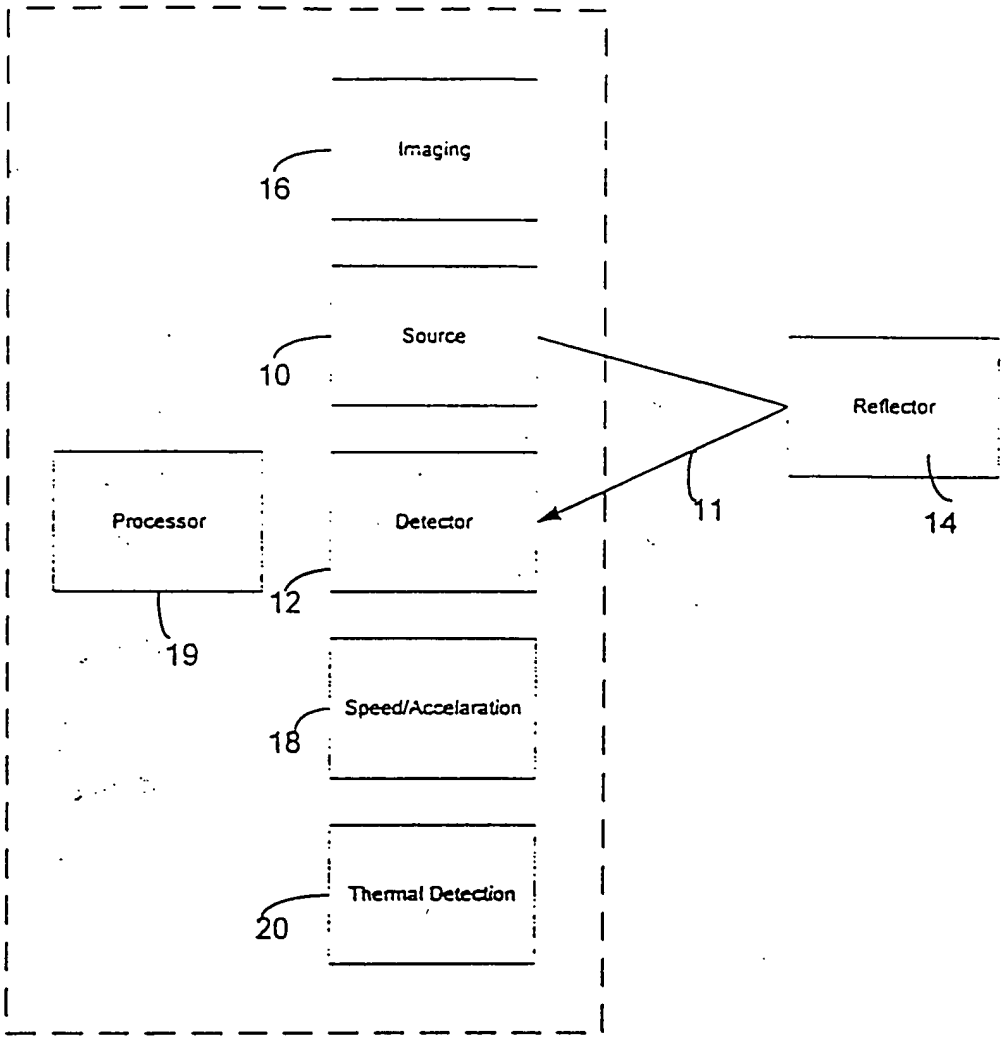

Imaging
16
Source
10
Reflector
Processor
Detector
11
14
12
19
Speed/Accelaration
18
Thermal Detection
20

Fig. 6

Blaise, Bradford C.

From: Blaise, Bradford C.

Sent: Tuesday, November 19, 2002 3:35 PM

To: 'James_Johnson@md-lasertech.com'; 'JJohnson@md-lasertech.com'; 'James.Johnson@md-lasertech.com'; 'Jim@md-lasertech.com'

Subject: Patent Matters

Re: U.S. Patent Application

Serial No.: 09/840,080

Filed: April 24, 2001

Inventor(s): James H. Johnson, John DiDomenico

Title: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR"

Dear Mr. Johnson,

As you know, Envirotest Systems Corp. (ESP) has filed a series of patent applications for which you are a named inventor.

In particular, the above-referenced patent application is a continuation of 09/648,534 filed on August 28, 2000 (now abandoned), which is a continuation of 09/480,688 filed on January 11, 2000 (now abandoned), which claims priority from provisional patent application 60/115,537 filed on January 12, 1999.

Moreover, the above-referenced patent application is identical to 09/648,534 and 09/480,688, meaning that all three applications comprise the same specification, drawings, and claims.

Recently, we tried to send you the following documents via Fed Ex to your last known home address of 4401 West Crestfield Road; Tucson, AZ. 85475:

(1) A copy of the patent application that was filed for 09/840,080;

(2) Joint Declaration and Power of Attorney; and

(3) Assignment to ESP.

The Fed Ex was not delivered due to an incorrect address. Accordingly, at this time, we ask that you provide us with your current home address so that we may resend these documents.

Patent rights and the administrative procedures for securing patent rights are costly and time sensitive. Any delay on your part may generate additional expenses for ESP and could jeopardize the company's valuable patent rights. I also remind you of your continuing duty, pursuant to your former employment, to assist ESP in securing its rights. Accordingly, we request a response within five (5) days of the date of this e-mail. If we receive no response from you within five days we will consider it a refusal to cooperate.

If you have any questions, please feel free to contact me.

Best Regards,

Brad

Bradford C. Blaise, Esq.
Mintz Levin Cohn Ferris Glovsky and Popeo, PC
12010 Sunset Hills Road - Suite 900
Reston, Virginia 20190
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Bradford C. Blaise, Esq.

703 464 4800
703 464 4895 *fax*

Direct dial 703 464 8130
bcblaise@mintz.com

November 12, 2002

Via Federal Express **CONFIDENTIAL**

Mr. John DiDomenico
8810 East Bear Paw Place
Tucson, Arizona 85749

Re: U.S. Patent Application
Serial No.: 09/840,080
Inventor(s): James H. Johnson, John DiDomenico
Title: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR"
Filed: April 24, 2001

Dear Mr. DiDomenico,

As you know, Envirotest Systems Corp. (ESP) has filed a series of patent applications for which you are a named inventor.

In particular, the above-referenced patent application is a continuation of 09/648,534 filed on August 28, 2000 (now abandoned), which is a continuation of 09/480,688 filed on January 11, 2000 (now abandoned), which claims priority from provisional patent application 60/115,537 filed on January 12, 1999.

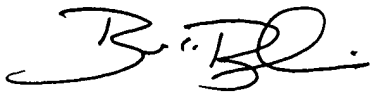
Moreover, the above-referenced patent application is identical to 09/648,534 and 09/480,688, meaning that all three applications comprise the same specification, drawings, and claims. A copy of the patent application that was filed for 09/840,080, 09/648,534, and 09/480,688 is enclosed.

Also enclosed are: (1) Joint Declaration and Power of Attorney; and (2) Assignment. At this time, we request that you execute the Declaration and Power of Attorney and Assignment documents, and return them to us as soon as possible for filing with the U.S. Patent and Trademark Office. For your convenience, I have enclosed a self-addressed Federal Express envelope for expeditious return.

Patent rights and the administrative procedures for securing patent rights are costly and time sensitive. Any delay on your part may generate additional expenses for ESP and could jeopardize the company's valuable patent rights. I also remind you of your continuing duty, pursuant to your former employment, to assist ESP in securing its rights. Accordingly, we request a response within ten (10) days from the date of this letter. If we receive no response from you within ten days we will consider it a refusal to sign.

If you have any questions regarding this matter, please do not hesitate to contact me at the telephone number listed above.

Very truly yours,



Bradford C. Blaise

BCB/mrs

Enclosures:

- Copy of U.S. Patent Application Serial No. 09/840,080 titled: "REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR," including drawing figures 1-6.
- Joint Declaration for Patent Application and Power of Attorney
- Assignment
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RES 77187v1

JOINT DECLARATION FOR PATENT APPLICATION

As the below named inventors, we hereby declare that:

Our residence, post office addresses and citizenship are as stated below next to our names;

We believe that we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled **REMOTE VEHICLE EMISSIONS SENSING DEVICE WITH SINGLE DETECTOR**, the specification of which

( ) is attached hereto.
(X) was filed on **April 24, 2001** as Application Serial Number **09/840,080** and was amended on

_____
(if applicable)

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

Prior Foreign Application(s)

We hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Country	Application Number	Date of Filing (day, month, year)	Date of Issue (day, month, year)	Priority Claimed Under 35 U.S.C. 119
				Yes ☐ No ☐
				Yes ☐ No ☐

Prior United States Provisional Application(s)

We hereby claim the benefit under 37 C.F.R. §119(e) of any United States provisional application(s) listed below:

Application Number	Date of Filing (day, month, year)	Status - Patented, Pending, Abandoned
60/115,537	12 January 1999	

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
12010 Sunset Hills Road, Suite 900
Reston, VA 20190
703-464-4800
fax: 703-464-4895

Prior United States Application(s)

We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below, and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Number	Date of Filing (day, month, year)	Status - Patented, Pending, Abandoned
09/480,688	11 January 2000	Abandoned
09/648,534	28 August 2000	Abandoned

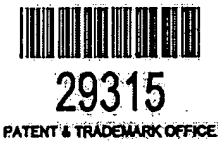
I hereby appoint the attorneys and/or agents associated with Mintz Levin Cohn Ferris Glovsky & Popeo,

Customer Number 

to prosecute this application and to transact all business in the

Patent and Trademark Office connected therewith.

Please address all telephone calls to **James G. Gatto** at telephone number 703-464-4800

Please address all correspondence to: 

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
12010 Sunset Hills Road, Suite 900
Reston, VA 20190
703-464-4800
fax: 703-464-4895

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature _____ Date _____

Full Name of Second Innventor	**JOHNSON** Family Name	**James** First Given Name	**H.** Second Given Name
Residence	**4401 W. Crestview Road, Tucson, Arizona 85475**		
Citizenship	**U.S.A.**		
Post Office Address	**Same as above**		

Signature _____ Date _____

Full Name of First Inventor	**DIDOMENICO** Family Name	**John** First Given Name	 Second Given Name
Residence	**8810 East Bear Paw Place, Tucson, Arizona 85749**		
Citizenship	**U.S.A.**		
Post Office Address	**Same as above**		

Mintz, Levin, Cohn, Ferris, Glovsky and Popeo
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Reston, VA 20190
703-464-4800
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ASSIGNMENT

WHEREAS, **James H. Johnson,** a citizen of the United States of America, residing at **4401 West Crestfield Road, Tucson, AZ 85475**; and **John DiDomenico**, a citizen of the United States of America, residing at **8810 East Bear Paw Place, Tucson, AZ 85749** (hereinafter "Assignor" or "Assignors"), have made an invention entitled

REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR

described in the application for United States Letters Patent filed on April 24, 2001, and assigned **U.S. Application Serial No. 09/840,080**, which is a continuation of **U.S. Application Serial No. 09/648,534**, filed August 28, 2000 (now abandoned), which is a continuation of **U.S. Application Serial No. 09/480,688**, filed January 11, 2000 (now abandoned) and which claims priority to **U.S. Provisional Application Serial No. 60/115,537**, filed January 12, 1999; and

WHEREAS, **Envirotest Systems Corporation** (hereinafter "Assignee"), a Delaware corporation having a place of business at 11 Kripes Road, East Granby, Connecticut 06026, is desirous of acquiring the entire right, title and interest in and to the aforesaid invention, applications and all Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes and divisions which may be granted therefor;

NOW THEREFORE, in consideration of the sum of One Dollar ($1.00) and other good and valuable consideration, the receipt of which is hereby acknowledged, the said assignors, by these presents do sell, assign and transfer unto Assignee, its successors, legal representatives and assigns, the full and exclusive right in and to the said invention as described in the said application, and in and to any Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes and divisions which may be granted therefor and all rights to claim priority on the basis of said application;

AND WE HEREBY authorize and request the Commissioner of Patents and Trademarks or any other proper officer or agency of any country to issue all said Letters Patent to said Assignee;

AND WE HEREBY warrant and covenant that we have the full right to convey the entire interest herein assigned and that we have not executed and will not execute any instrument or assignment in conflict herewith;

AND WE HEREBY authorize any attorney and/or agent of Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, PC, to insert any information necessary to ensure that this Assignment is complete upon submission to the United States Patents and Trademark Office;

AND WE HEREBY agree to communicate to said Assignee or its representatives any facts known to us respecting said invention, to execute all divisional, continuation, reissue, reexamination, extension, substitute and foreign applications, sign all lawful documents and make all rightful oaths and declarations relating to said invention, execute and deliver any and all papers that may be necessary or desirable to perfect the title to this invention in said Assignee, its successors, legal representatives or assigns, and to testify in any judicial or administrative proceeding and generally do everything possible to aid the said Assignee to obtain and enforce said Letters Patent in the United States or any foreign country when requested so to do by said Assignee.

Signature of Inventor: _____

Inventor's Name: **James H. Johnson**

Date of Execution: _____

IN WITNESS WHEREOF, I have hereunto set my hand and seal.

County of)
) ss:
)

On this _____ day of _____, 2002, before me a Notary Public in and for the County and State aforesaid, personally appeared **James H. Johnson**, to me know to be the person whose name is subscribed to the within instrument and acknowledged that he executed it of his own free act and deed.

(SEAL)

_____
Notary Public

My commission expires: _____

Signature of Inventor: _____

Inventor's Name: **John DiDomenico**

Date of Execution: _____

IN WITNESS WHEREOF, I have hereunto set my hand and seal.

County of)
) ss:
)

On this _____ day of _____, 2002, before me a Notary Public in and for the County and State aforesaid, personally appeared **John DiDomenico**, to me know to be the person whose name is subscribed to the within instrument and acknowledged that he executed it of his own free act and deed.

(SEAL)

_____
Notary Public

My commission expires: _____

REMOTE VEHICLE EMISSION SENSING DEVICE WITH SINGLE DETECTOR

Field of the Invention

The present invention relates generally to filter/detector arrangements for use in remote vehicle emissions analysis and remote sensing devices.

Background of the Invention

Remote sensing devices may be used to detect and characterize emissions from a vehicle. One device for performing such a process analyzes radiation that passes through the vehicle emission using a detector. Various components of the vehicle emission absorb radiation of specific characteristic wavelengths. A filter is used to permit only a radiation band including the characteristic wavelength of interest to reach the detector. If multiple components of the emission are to be analyzed in this manner, multiple sets of detectors and filters are generally necessary to carry out such measurements.

A known device for the remote sensing of vehicle emissions is depicted in Fig. 1. A beam (1) from a radiation source (7) passes through emissions plume (8) of vehicle (9) and is reflected from mirror (2) onto reflecting wheel (3). Beam (1) is then reflected from reflecting wheel (3) to one of a group of mirrors (4). The group of mirrors (4) focus and reflect the beam (1) through

respective filters (5) and onto respective detectors (6). One such remote sensing device is disclosed in U.S. Patent No. 5,210.702.

Such devices, however, may have certain drawbacks. These devices may have a large number of parts to manufacture, assemble, align, maintain, and calibrate, including special reflectors, multiple detectors and multiple light filters. Each of these parts introduces error into the final measurements. For example, light filters may suffer from light bleed, allowing undesirable wavelengths of light to reach the detectors. Uncertainty as to the measurements may also occur because different detectors may react differently to the variety of conditions encountered during the use of these devices.

Additionally, use of multiple filters, detectors, reflectors, and the like can add considerable complexity and bulk to the device. Also, if other components of the emission are to be detected, the replacement of filters and/or detectors to provide suitable filters and detectors for such other components may involve considerable cost in parts, as well as in assembly, alignment, and calibration of the device.

Another gas analysis device is disclosed in U.S. Patent No. 4,678,914. This device employs an infrared (IR) gas analyzer in which IR radiation from a source is directed toward an IR detector. The IR radiation passes through both a gas located in a sample cell and then one of various light filters mounted on a continuously rotating filter wheel. This device requires close proximity to an emissions output in order to operate properly, and employs a sample chamber for gas analysis. Devices which employ a gas sample chamber are not feasible

for remote sensing of vehicle emissions because of the need to collect a sample of the emission and isolate it in the gas sample chamber. Also, such devices only provide a localized reading of the gas at the exact point where the sample is taken.

These and other drawbacks of known devices exist.

Summary of the Invention

An object of the present invention is to overcome these and other drawbacks in existing devices.

Another object of the present invention is to provide greater flexibility in remote vehicle emissions sensing devices by allowing multiple different components to be detected without using multiple detection units.

Another object of the present invention is to provide greater accuracy and certainty in remote vehicle emissions sensing devices by reducing the number of detectors used in such devices to thereby reduce uncertainty caused by use of several different detectors under changing ambient conditions.

One aspect of the present invention provides a device including a radiation source, a detector, and a plurality of filters. A beam from the radiation source passes through the emission plume of a vehicle, and one of the plurality of filters which is aligned with the detector to the detector. When a different component of the emission is to be analyzed, the filter which is aligned with the detector is changed and the detection process is repeated.

Another aspect of the invention provides a method for remotely sensing vehicle emissions by passing a beam from a radiation source through a vehicle emission plume and one of a plurality of filters which is aligned with a detector to the detector. The method may also include the step of moving the filters to align different filters with the detectors or moving the detector to allow the detector to be aligned with different ones of the filters.

Other aspects and advantages of the invention will be apparent from the detailed description of the preferred embodiments which follows.

Brief Description of the Drawings

Fig. 1 illustrates a known remote vehicle emissions sensing device.

Fig. 2a illustrates an embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 2b illustrates another embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 3 illustrates a wheel with filters mounted thereon which may be employed in accordance with the present invention.

Fig. 4 illustrates moveable filters and a detector located in a sealed housing according to another embodiment of the present invention.

Fig. 5 illustrates another embodiment of a remote vehicle emissions sensing device of the present invention.

Fig. 6 shows a schematic block diagram of the components of an embodiment of a remote vehicle emission sensing device in accordance with the present invention.

Detailed Description of the Preferred Embodiments

The present invention, as illustrated in Figs. 2a and 2b, is intended for use in a system for the remote sensing of vehicle emissions, whereby a variety of different components of the vehicle emission are sensed by passing a beam of radiation through the vehicle emission plume. After passing through the emission plume, the beam, which may include ultraviolet radiation and/or infrared radiation, is received by a detector. The concentrations of various components of the vehicle emission plume may be calculated by determining the amount of radiation of certain characteristic wavelengths which has been absorbed from the beam by the emission components of interest upon passage through the vehicle emission plume.

Fig. 2a illustrates one embodiment of a remote sensing device ("RSD") in accordance with the present invention. A beam (11) from a radiation source (10) passes through an emission plume (12) of a vehicle (16). The beam (11) may optionally be focused on a detector (14) by lens (13). The light beam (11) also passes through a set of moveable filters (15) before it impinges on detector (14).

In the present invention, moveable filters (15) allow a single detector (14) which has a broad enough frequency response to cover all of the detection

bands of interest, to measure different components of the vehicle emission plume. Alternatively, two or more detectors (14) can be employed to cover all of the detection bands of interest. Each filter (15) permits only a certain detection band of radiation to reach the detector (14). Filters (15) may be pass through filters, which allow transmission of only certain wavelengths through the filters (15). Each of the various filters (15) is used to isolate different detection bands of radiation for detection of different components of the vehicle emission. Each detection band is carefully selected to be centered about a wavelength of radiation that is characteristic of the absorption pattern of a specific component of the vehicle emission. In this manner, radiation characteristic of each component of the vehicle emission can be isolated and impinged at different times upon the same detector (14).

The filters (15) may be moved so that one filter (15) at a time is aligned with only a single detector (14). The alignment is such that all radiation to be received by the detector (14) must first pass through the aligned filter (15). A single RSD may be employed to detect multiple components of a vehicle emission without requiring more than one detector (14) because the present invention allows a plurality of different detection bands to be directed to a single detector (14) using a moveable set of filters (15).

In another embodiment shown in Fig. 2b, a movable set of reflective filters (17) is used. A beam (11b) from a radiation source (10b) passes through an emission plume (12b) of a vehicle (16b). The beam (11b) may optionally be focused on a detector (14b) by lens (13b) via reflection off of one or more of a

moveable set of reflective filters (17). Reflective filters (17) may reflect only the wavelengths of specific detection bands of radiation for detection of different components of vehicle emission plume (12b)

In an embodiment shown in Fig. 3, the moveable set of filters (23) may comprise a rotating filter wheel with filters mounted on the wheel. As illustrated in Fig. 3, the filter wheel (21) is mounted for rotation about its axis (22). Various filters (23) are mounted on the filter wheel (21). Thus, in this embodiment, the filter wheel (21) may be rotated on its axis to align different filters (23) with a single detector at different times. As noted previously, each filter (23) permits only a specific detection band of radiation to reach the detector by transmission or reflection. Each detection band is centered on a wavelength of radiation that is characteristic of the absorption pattern of a specific component of the vehicle emission. Each filter (23) on the wheel (21) passes a detection band of radiation which corresponds to a specific vehicle emission component to be detected. The wheel (21), and therefore the filters (23), rotate so that multiple vehicle emission components may be sequentially detected and analyzed using a single detector.

The filter wheel (21) may be provided with a plurality of notches (24) which may periodically activate an optical switch (not shown) whereby the processor (19) can associate a particular detector reading with a particular one of filters (23) so that the reading can be linked to the component of the exhaust being measured. Any other suitable means for informing the processor (19) which filter (23) is associated with a particular detector reading may be

employed. For example, the filter wheel (21) may be rotated stepwise and for each step of rotation a signal may be sent to the processor.

Preferably, one of the filters (23) corresponds to a reference channel having a transmission bandwidth centered at a wavelength of 3.9 microns. This reference channel can be employed to determine background noise and/or exhaust opacity, if desired.

In another embodiment of the invention shown in Fig. 4, moveable filters (41) and a detector (42) are placed in a sealed housing (43). By placing moveable filters (41) and a detector (42) in a sealed housing (43), undesired radiation may be prevented from impinging on the detector (42) or entering the filters (41). The sealed housing (43) may have, for example, a single opening (44) to allow a beam (45) from a source (47) to enter after passing through vehicle emissions plume (48) of vehicle (49). As illustrated in other embodiments, a focusing mirror (46) may be used to focus beam (45) onto the detector (42). Moveable filters (41) and a detector (42) may be aligned in such a manner as to receive beam (45) at the detector (42) through a single one of filters (41).

In another embodiment of the invention, a general filter (50) may be placed in the path before the detector to prevent unwanted radiation from reaching the detector. A general filter (50) may be used, for example, to eliminate radiation outside a broad detection band which includes radiation of wavelengths within a series of narrower detection bands specific to each of the components of interest. The general filter (50) may alternatively be employed

to filter out specific radiation components such as all visible light, all ultraviolet light, etc. In one embodiment of the invention, a beam from the radiation source includes radiation having wavelengths in the broad detection band of 3 to 6 microns, and a general filter (50) may be configured to prevent all other light from reaching the detector (42) and/or the filters (41). Thus, a general filter (50) may be placed at the single opening (44) of a sealed housing (43). Movable filters (41) are then aligned so that a beam (45) impinging on the detector (42) passes through a desired one of filters (41) before reaching the detector (42).

Other embodiments of the invention are also envisioned. In a further alternative embodiment (not shown), the moveable filters (41) slide into alignment with the detector (42). In another embodiment, the filters are stationary, and the detector (42) may be moved to align it with the appropriate filter. As illustrated in Fig. 5, a beam (52) from radiation source (51) passes through a vehicle emission plume (53) of a vehicle (53a). Beam (51) reflects off of mirror (54) onto reflecting wheel (55). Reflecting wheel (55) directs beam (51) through respective focusing lenses (56) to focus the beam (51) through filters (57) and onto detector (58). Detector (58) is moveable in slot (59) so that it may be aligned with the appropriate one of filters (57). Other variations on this embodiment of the invention are also possible.

A method of remotely sensing vehicle emissions is also contemplated in the present invention. Using the structure of the present invention, vehicle emissions may be sensed by emitting radiation from a radiation source and

passing the radiation through a vehicle emission plume. The method is continued by passing radiation through one of a plurality of filters, receiving the radiation at a detector, and determining the concentration of one or more components of the vehicle emissions from the detector response.

As noted previously, the filters may be located on a wheel mounted for rotation about its central axis. In one embodiment of the invention, the wheel rotates at a constant speed. In another embodiment of the invention, the wheel only rotates when a vehicle emission plume is present in the light beam.

The present invention improves on known devices by eliminating the need for multiple sets of filters and corresponding detectors, and reducing the number of parts needed. Use of moveable filters or a moveable detector may eliminate the need for multiple detectors, (6), multiple mirrors, (4), and a reflecting wheel, (3), which are employed in the conventional device shown in Fig. 1. Additionally, multiple vehicle emission components may also be determined without having to align a reflecting wheel (3), multiple mirrors (4), multiple filters (5), and multiple detectors (6). As illustrated in Fig. 2, the beam (11) may be directed through one of the moveable filters (15) which is currently aligned with the detector (14). This saves time, effort, and expense when manufacturing and repairing the RSD. Additionally, filter wheel (15) may be easily changed, thus allowing a series of different components in the vehicle emission to be detected by providing a series of new filters which permit passage of radiation within the appropriate detection bands for the different components.

The RSD of the present invention allows detection of vehicle emissions in an open area. There is no need for a cell or chamber in which to gather the emission plume to determine the concentrations of various components thereof. Further, this configuration allows a single RSD of the present invention to sequentially sense the vehicle emissions of multiple vehicles over a short time span to thereby make remote roadside vehicle emission sensing practicable.

Further, the RSD unit of the present invention may be a mobile RSD which is capable of being moved to a number of locations. In one embodiment, the RSD is placed at an exit ramp of a highway, and is used to remotely determine components of vehicle emissions. Some time later, the RSD may be moved to a different location and employed at the new location to sense the same or different components of vehicle emissions.

Fig. 6 illustrates a schematic representation of components of a RSD in which the present invention may be employed. Embodiments of the invention may include some or all of the various components as described below.

Radiation Source

Preferably, an RSD unit comprises a source of electromagnetic radiation 10 which may be used in the absorption spectroscopy measurement of vehicle exhaust emissions. Preferably, source 10 may comprise an infrared (IR) radiation source producing beam 11. Some embodiments of the RSD may include other types of radiation sources, for example, an ultraviolet (UV) source, a visible light source, or a combination of sources.

Radiation Detector

The RSD unit may further comprise a detector 12 of electromagnetic radiation. The detector 12 is preferably chosen to permit detection of electromagnetic radiation emitted by the source. For example, the detector 12 may comprise a photodetector (*e.g.*, a photodiode), a photomultiplier tube (PMT), a spectrometer or other suitable radiation detector. For embodiments using ambient radiation sources an appropriately sensitive detector may be used. For example, a mercury cadmium telluride (Hg Cd Te) photodetector may be used to detect ambient IR radiation. Other detectors are possible.

Reflector

According to one embodiment, the RSD unit may comprise a reflector 14 mounted in a manner to allow radiation from the source 10 to be reflected into the detector 12 for analysis. The reflector 14 may comprise a mirror, prism, diffraction grating, beam splitter or other device suitable for reflecting the radiation of the source 10. The reflector 14 may form part of the detection unit in which case the reflector 14 may function to split the radiation beam among one or more detectors, focus the radiation beam onto one or more detectors or redirect the radiation beam to the appropriate detection for detection of a particular species. In addition, plural reflectors 14 may be employed to accomplish one or more of these functions in any combination.

In another embodiment the reflector 14 may comprise a lateral transfer mirror used to reflect the source 10 radiation back along a path displaced laterally (or vertically) from the path between source 10 and reflector 14. In

this embodiment, the reflector generally does not form part of a detection unit but rather is located remotely from the detection unit. The primary purpose of transfer mirrors is to redirect the radiation to the detector unit. A variety of different transfer mirrors may be employed in the RSD unit depending primarily upon the particular spatial relationship of the radiation source 10, detector 12 and reflector 14 which is to be employed by the RSD unit. Several configurations are described below, some of which require different types of transfer mirrors to redirect the radiation beam to the detector unit.

Imaging Unit

The RSD unit may also include an imaging unit 16 which may be used to capture or record an image of a vehicle passing through the detection system. The imaging unit 16 may be arranged to record an image of a vehicle at a specified location in the detection system. The imaging unit 16 may comprise, for example, a camera, such as a film, video or digital camera. Other imaging devices may also be used.

Preferably, the imaging unit 16 may record an image of the vehicle identification tag (*i.e.*, license plate). Tag information may be processed, using a suitable data processor, to identify additional information about the respective vehicle. For example, Motor Vehicle Department databases may be accessed to retrieve vehicle owner information, vehicle make, model type, model year and other information. In some embodiments, this additional information may be incorporated into the emission sensing data analysis. For example, the make and model year of the vehicle may be used to input information (*e.g.*, whether

the vehicle includes a carburetor or fuel injector, etc.) into certain data processing routines.

Speed and Acceleration

The RSD unit may also include a speed and acceleration detection unit 18. Preferably, a vehicle's speed and acceleration through the detection system may be measured using speed detection unit 18. For example, the speed detection unit may comprise an arrangement of laser beams associated with timing circuitry. The arrangement of laser beams may be arranged to traverse the path of a vehicle at various points in the detection system. As a vehicle passes through the detection system it will cause interruptions in the laser beams. The times at which the beam interrupts occur may be used to calculate the vehicle's speed and acceleration. Other methods of detecting vehicle speed and acceleration may also be used. For example, radar systems or transducers (or piezoelectric elements) may be placed at locations in the roadway to monitor vehicle passage through the system. Preferably, the speed and acceleration data may be input into a data processing unit 19 to accurately characterize vehicle operation conditions (*e.g.*, accelerating or decelerating). Other uses of the speed and acceleration data are also possible.

Thermal Detection Unit

Some embodiments of the invention may incorporate a thermal detection unit 20. Preferably, the thermal detection unit 20 may comprise a non-contact thermometer system. For example, an IR thermometer may be

used to optically detect the temperature of remote objects. Other temperature detection systems may also be used.

Preferably, the thermal detection unit is used to detect the temperature of portions of the vehicle passing through the RSD system. Some embodiments may use direct sensing of the area of interest. For example, an IR thermometer may be aimed at the underside of a passing vehicle to detect the temperature(s) of vehicle components (*e.g.*, engine, catalytic converter, muffler, etc.). Indirect sensing may also be used. For example, an IR thermometer may be aimed at the roadway to measure the heat reflected from the underside of a vehicle.

Preferably, the thermal information recorded by the thermal imaging unit 20 may be incorporated into the processing for the vehicle emission data. For example, a temperature reading of a vehicle's engine may indicate that the engine has just recently been started (*i.e.*, the engine is "cold" or has not reached normal operating temperature). Such a cold engine reading may initiate alternative data processing for the emission data.

Data from thermal detection unit 20 may also be used for other data handling procedures. For example, it may be preferable to identify whether a vehicle's catalytic converter is operational. A temperature reading indicating that the catalytic converter is "cold" may indicate that the converter is not functioning. However, a cold catalytic converter might also indicate that the vehicle has only been driven for a short period and, thus, has not achieved operational temperature. Embodiments of the present invention reduce the chance of such a potentially misleading reading by detecting the temperature of

other portions of the vehicle. For example, a temperature reading indicating that the catalytic converter is cold, but the brake rotor (or engine) is "hot" indicate, with greater certainty, that the vehicle has reached operating temperature and the catalytic converter is indeed non-operational. Other uses for collected thermal data are also possible.

Thermal detection unit 20 may comprise various detection apparatus configurations. For example, two thermal detectors may be arranged to view a vehicle traveling in a traffic lane. Preferably, the thermal detectors are positioned at points affording different angles of view at the vehicle. The thermal detectors may be positioned near the locations of speed and acceleration detection units (*i.e.*, spaced with some distance between detectors). Spatial separation of the detectors and use of differing angles of view increase the likelihood of detecting the temperature of the areas of interest on the vehicle (*e.g.*, the engine, catalytic converter, etc.) and also afford a time sequence of measurements (*i.e.*, the vehicle crosses one detector, then the other at a later time). In some embodiments, an additional thermal detector may be incorporated. The additional thermal detector may be positioned at a suitable location to detect the temperature of the front of the vehicle (*e.g.*, the radiator or engine). For example, the additional thermal detector may be positioned at either side of the lane at a sufficient height to detect the front of the vehicle, or be embedded into the lane to record a head-on view of the vehicle.

Some embodiments may include arrays of thermal detectors to achieve an even greater likelihood of detecting the desired temperature readings. For

example, in an embodiment incorporating an IR thermometer, an array of detection beams may be aimed at the vehicle. The array may span vertical and horizontal regions. Using such an array of detection beams allows the thermal detection unit 20 the ability to detect the temperature of vehicles of varying size and shape. In addition, some of the beams in the array may be used to detect reflected heat off of the lane. Using an array of detector beams may also result in greater accuracy in temperature measurements. The focal point of each detection beam in the array can be narrowed to detect the temperature of a smaller region of interest. In this manner, a more accurate temperature of each point may be obtained. For example, a detector beam with a focal point four inches in diameter will take an average temperature over the whole four inch region within the focal point. If the region of interest happens to be a one inch exhaust pipe on a vehicle, the detector will average the temperature of the region of interest (*i.e.*, the pipe comprising one-fourth of the focal region) with objects outside of the region of interest (*i.e.*, the other three fourths of the focal region) resulting in a less accurate temperature reading. In contrast, an array of smaller focal point detector beams (*e.g.*, one inch in diameter each) will be more likely to detect an accurate temperature of the region of interest (*e.g.*, a one inch exhaust pipe).

These and other thermal detection techniques may be used advantageously in a remotely operated unit, but are not limited to such use. They may also be used in other RSD systems as well.

Processing Unit

The RSD unit preferably includes a data processing unit 19 to carry out analysis of detected data, among other things. The processing may be accomplished using a suitable processing device, for example, a computer or other microprocessor. The processing unit 19 may include software to accomplish desired analysis of collected data. For example, the software may be used to calculate the concentrations of various exhaust gas constituents (*e.g.*, HC, CO_2, NO_x, CO, etc.), the decay rate (*e.g.*, dissipation in time) of the exhaust constituents, the opacity of the exhaust plume, the temperature, speed and acceleration of the vehicle, and other calculations. In one embodiment, software may be used to calculate detected ratios between CO_2 and other exhaust components. The software may make comparisons to threshold concentration values or emission profiles for characterization of vehicles as high or low emitting vehicles and to ensure compliance with predetermined emission standards.

The processing unit may also comprise software routines to accomplish other data analysis functions. For example, the vehicle emission data may be checked for running losses. Running losses may typically include emission readings due to fuel system leaks on a vehicle (*e.g.*, leaky fuel tank filler cap, fuel line, etc.), blow by emissions (*i.e.*, emissions due to other vehicles in the vicinity) or other systematic losses.

The data processing may also include software routines to accomplish various vehicle owner notification processes. For example, a vehicle owner of

a vehicle that has been recorded as "clean" (*i.e.*. in compliance with certain predetermined emission levels) may, upon a second recording of "clean," receive notification of the fact. Coordination with local authorities may be arranged to grant vehicle owners a waiver or pass of local emission certification procedures upon receiving such clean notification. Likewise, owners of vehicles that fail to meet predetermined emission levels may receive notification requiring the owner to remedy the non-compliance. Other data processing functions are possible.

Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. The specification and examples should be considered exemplary only. The scope of the invention is to be determined by the claims appended hereto.

Claims

What is claimed is:

--1.-- --A gas analysis device for remotely determining at least one characteristic of a vehicle emission plume comprising:

a radiation source;

a plurality of moveable filters sequentially positionable to receive radiation from said radiation source after the radiation has passed through a vehicle emission plume, each of said filters being capable of filtering out radiation except for a predetermined wavelength band; and

a detector positioned such that radiation from said radiation source may be sequentially directed onto said detector via at least two filters to thereby produce a plurality of detector responses proportional to the intensity of radiation directed onto the detector via said at least two filters.

2. The device according to claim 1, wherein said plurality of filters are arranged on a moveable filter wheel.

3. The device according to claim 2, wherein the filter wheel and the detector are housed in a housing which is sealed to substantially prevent radiation from reaching the detector except via one of said filters.

4. The device according to claim 1, further comprising a general filter which removes substantially all visible light from a radiation beam passed through said general filter, said general filter being positioned such that a beam from said radiation source must pass through said general filter after passing through a vehicle emission plume and before reaching said detector.

5. The device according to claim 1, wherein said plurality of filters comprise at least one reflective filter.

6. The device according to claim 1, wherein said plurality of filters comprise at least one pass through filter.

7. The device according to claim 1, wherein said radiation source projects a beam of infrared radiation across the path of a moving vehicle.

8. The device according to claim 1 further comprising a processor for processing at least one detector response to provide information about the composition of an exhaust plume of a moving vehicle.

9. The device according to claim 8 further comprising an indicator for informing the processor which filter is optically aligned with the detector for a particular detector response.

10. A method for remotely determining at least one characteristic of a vehicle emission plume comprising the steps of:

a) providing a source of radiation and a plurality of filters each of which is capable of filtering out radiation except for radiation in a predetermined wavelength band;

b) directing radiation from the source through an emission plume of a moving vehicle to a first filter and then to a detector;

c) generating a first detector response indicative of the intensity of radiation received by the detector;

d) positioning a further filter such that the radiation from the source is directed through the exhaust plume of the moving vehicle to the further filter and then to the detector;

e) generating a further detector response indicative of the intensity of light received by the detector via the filter positioned in step d);

f) optionally repeating a sequence of steps d) - e) to obtain an additional detector response for each repetition of the sequence; and

g) determining at least one characteristic of the vehicle emission plume from said detector responses.

11. The method according to claim 10, wherein the plurality of filters are arranged on a filter wheel, and the step of moving the plurality of filters comprises rotating the filter wheel.

12. The method according to claim 10, further comprising the step of passing the radiation from the emission plume through a general filter to remove substantially all light having a wavelength outside a predetermined broad detection band prior to directing said radiation to the plurality of filters.

13. The method according to claim 10, wherein the plurality of filters and the detector are located within a housing which is sealed to substantially prevent radiation from reaching the detector except via one of said filters.

14. The method according to claim 10, wherein the source of radiation directs the radiation through the emission plume.

15. The method according to claim 14, wherein the source of radiation directs a beam of infrared radiation across the path of a moving vehicle.

16. The method according to claim 10, wherein the filters comprise at least one pass through filter.

17. The method according to claim 10, wherein the filters comprise at least one reflective filter.

18. A method for remotely determining at least one characteristic of a vehicle emission plume comprising the steps of:

a) providing a source of radiation and a plurality of filters each of which is capable of filtering out radiation except for radiation in a predetermined wavelength band;

b) directing radiation from the source through an emission plume of a moving vehicle to a first filter and then to a detector;

c) generating a first detector response indicative of the intensity of radiation received by the detector;

d) positioning the detector such that the radiation from the source may be directed through the exhaust plume to a further filter and then to the detector;

e) directing the radiation from the source to the filter positioned in step d) and then to the detector;

f) generating a second detector response indicative of the intensity of light received by the detector via the further filter;

g) optionally repeating a sequence of steps d) - f) to obtain an additional detector response for each repetition of the sequence; and

h) determining at least one characteristic of the vehicle emission plume from said detector responses.

19. The method according to claim 18, wherein the filters comprise at least one pass through filter.

20. The method according to claim 18, wherein the filters comprise at least one reflective filter.

Abstract of the Disclosure

A remote sensing device for determining at least one characteristic of a vehicle emission plume includes a radiation source, a detector, and a plurality of filters. Either the filters or the detector are movable relative to the other such that different filters, each of which is capable of filtering out radiation except radiation of a predetermined wavelength band, can be used to filter the radiation directed to the detector. Also disclosed is a method for remotely determining at least one characteristic of a vehicle emission plume using a single detector and a plurality of filters wherein either the detector or the filters are positionable relative to one another.

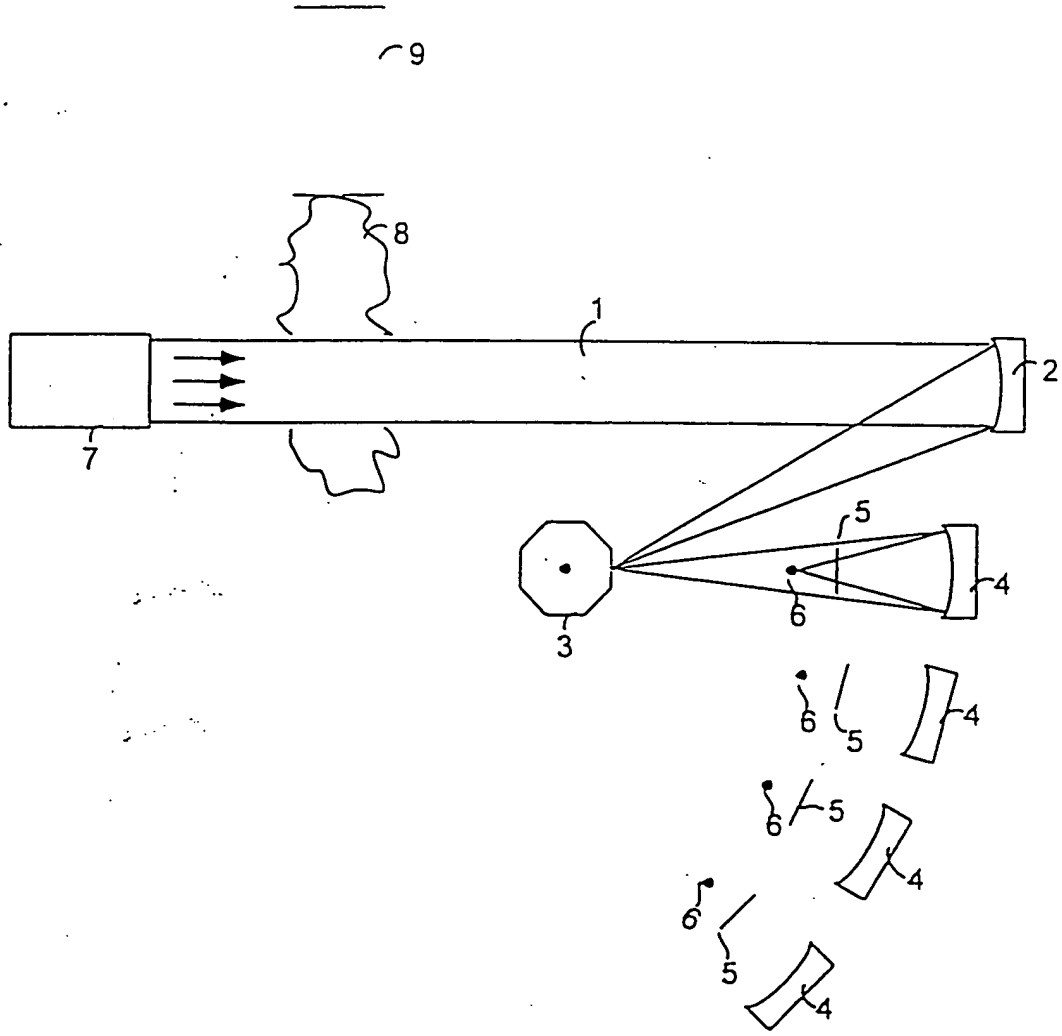

Fig. 1

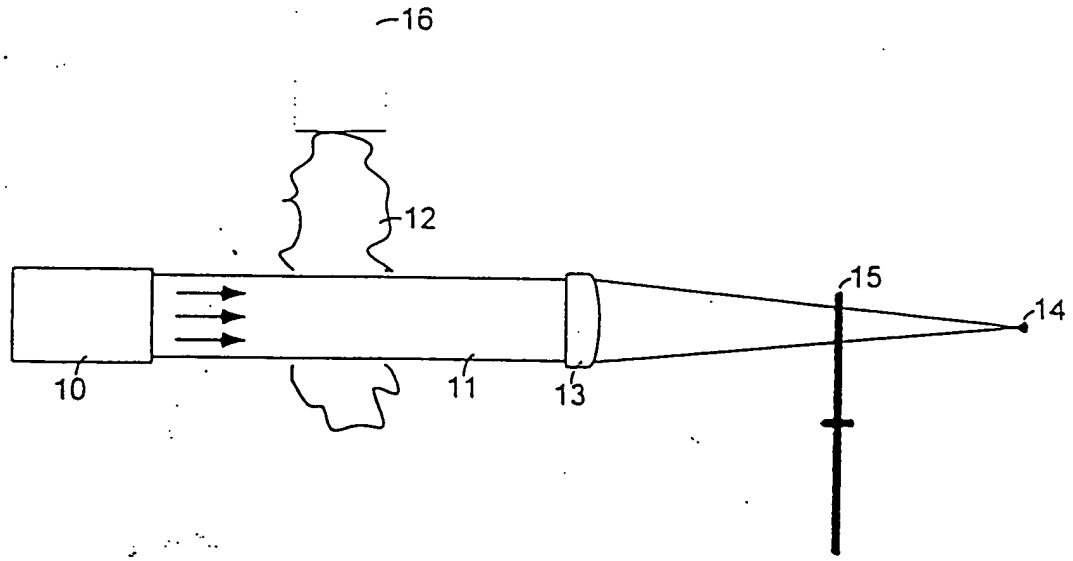

Fig. 2a

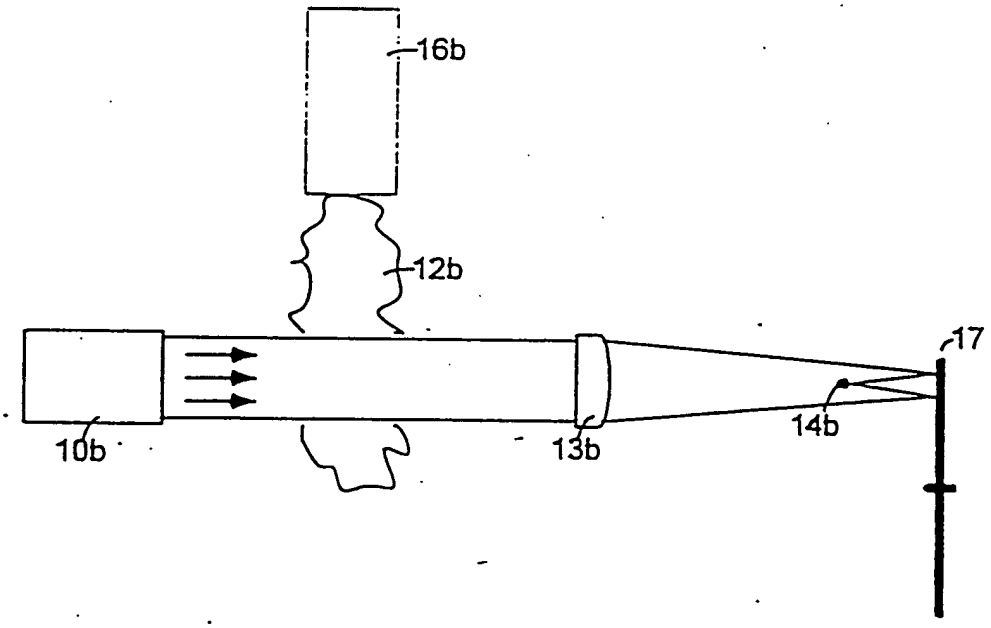

Fig. 2b

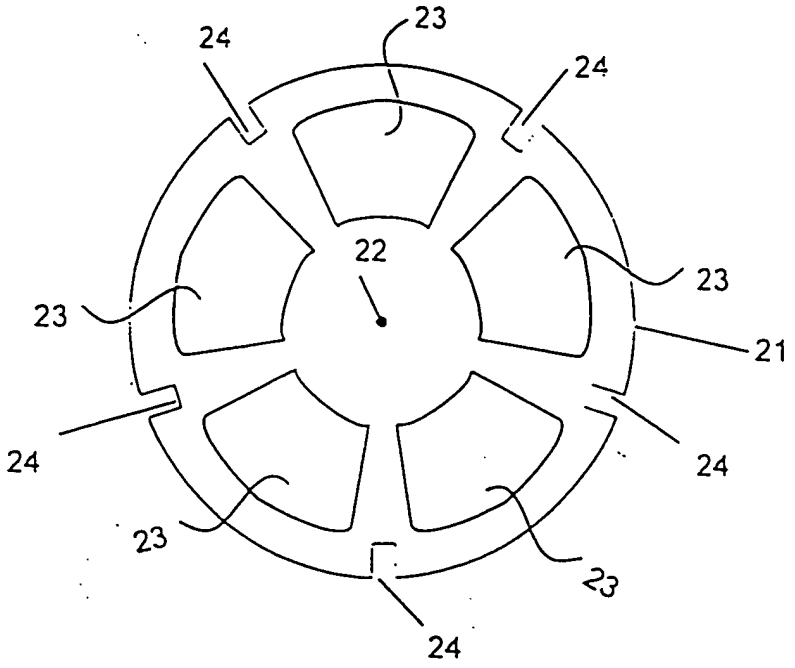

Fig. 3

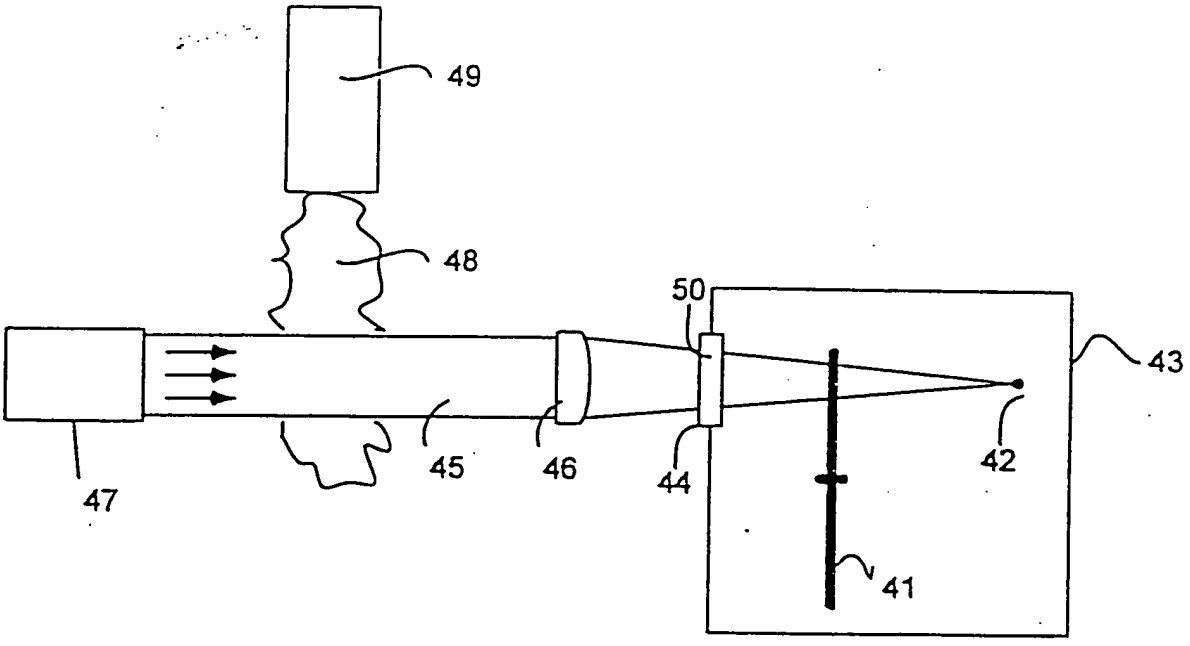

Fig. 4

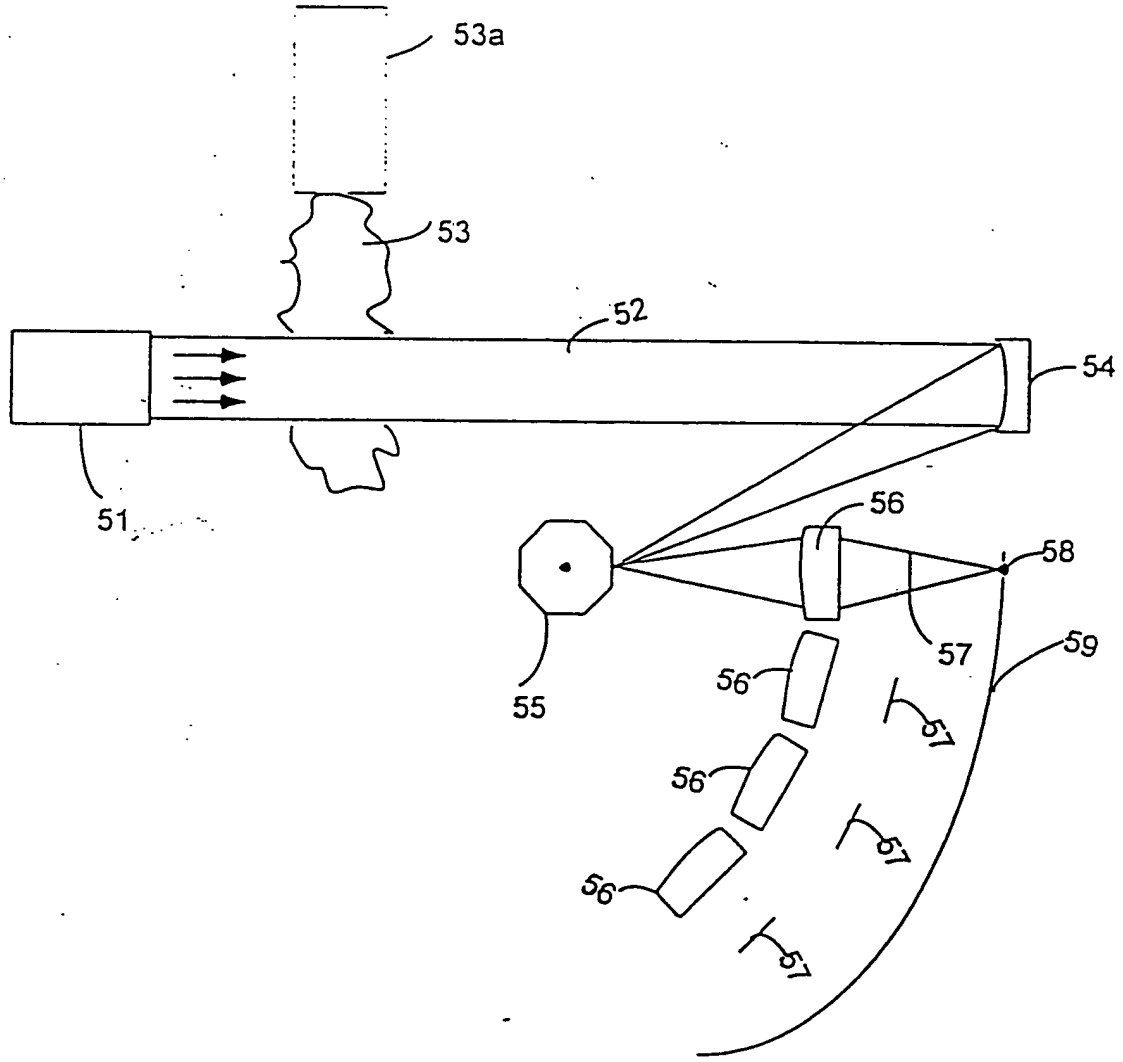

Fig. 5

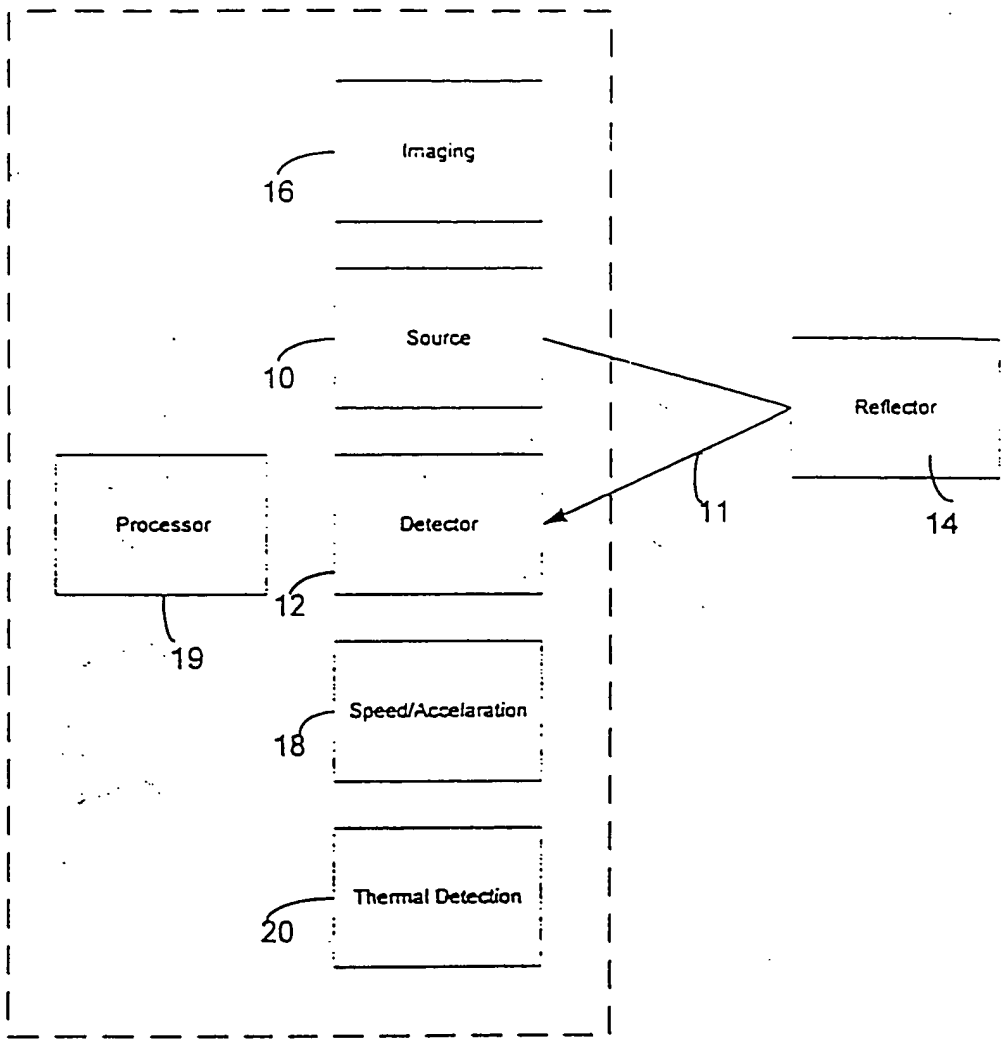
Imaging
16
Source
10
Reflector
11
14
Processor
Detector
12
19
Speed/Accelaration
18
Thermal Detection
20

Fig. 6

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